ELEMENTARY LESSONS IN PHYSICS

BY

J. B. GIFFORD

THOMPSON,
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15

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PREFACE.

The following Lessons have been growing into their present form for several years, during which time they have been used in classes under the supervision of the author. Within the past year they have been revised, with the aim of adapting them to general use.

It is confidently hoped that these Lessons will meet a want which is being increasingly felt by teachers and school officers for a suitable text-book to aid them in training the pupils of the upper grammar and lower high school grades to observe, to think, and to express thought, and in revealing to them some of the laws in accordance with which physical changes occur.

It has been the author's aim to guide the investigations of the learner by directions and questions so definite that he will generally be able to get the points desired without aid. Occasionally a question is asked which only a small proportion of the class may be able to answer; but the question should at least *secure the attention of all*, and prepare them to grasp the truth when it comes; and the closer workers will get the exercise which they need.

The *illustrations* have been introduced to show the *conditions* of the experiments, and not the *results.*

Messrs. Frank L. Keith, J. M. Dill, and Charles F. King, of Boston, Mr. Clarence Boylston, of Milton, Mass., and Mr. Preston Smith, instructor in Physics, Brockton, Mass., have kindly read through these Lessons in manuscript or in proof, and suggested many valuable improvements.

Whatever of merit there may be in the aim and general plan of the work should be largely credited to my esteemed teacher in Physics, Mr. George H. Martin, of Boston.

JOHN B. GIFFORD.

June, 1894.

CONTENTS.

Topics marked (†) are suggested for the earlier study, in schools in which this work is not confined to a single year.

Those marked (*) are suggested for the later study, where the work is distributed through two or more years.

SUGGESTIONS TO TEACHERS.

PUPILS *may* perform *at home* such of the experiments as do not call for special apparatus. Each teacher must decide for himself whether this plan is the most satisfactory for his class.

Wherever the experiments are performed, each pupil should *observe and infer for* himself, and *commit to writing* the results of his work before they are reported in the class exercises.

These records may be made upon separate sheets of paper of uniform size, each statement marked to correspond with the directions in the manual. If only one observation is called for under an experiment, it is marked *Obs.;* if more than one, they are numbered *Obs.* 1, *Obs.* 2, etc. In the same way inferences are marked, — *Inf.*, or *Inf.* 1, *Inf.* 2, etc. Other facts to be recorded under each experiment are usually numbered.

After these results have been reported and compared in the recitation, and opportunity given for correcting errors, by repeating experiments, it would seem well that they should be neatly recorded in note-books.

This material should form the *basis of much written language* work, in which the pupil should develop the subject assigned by *complete descriptions of experiments, with drawings of the apparatus* used.

For the *derivation of terms*, suggested as profitable language study, a list of the required prefixes and suffixes, with their meanings, will be found on page 157.

The work laid out in these Lessons may all be done with a class in a single year; but some will prefer to distribute it over a longer period, and the derivation of terms and many of the general topics *may be omitted* without hindering the study of the others.

ELEMENTARY LESSONS IN PHYSICS.

I. NATURE OF MATTER.

MATTER, IMPENETRABILITY.

OBSERVATION, DERIVATION, INFERENCE.

EXPERIMENT 1. (To be performed at home.)

FILL a bottle with water, and insert your pencil.
Observation. State what the water does.

(In NOTE-BOOK.*) *Experiment* 1. *Obs.* *Some of the water overflows.*

Inference. What causes it to do this?

(NOTE-BOOK.) *Inf.* 1. *The bottle was full of water, and there was no room for the pencil. So when the pencil was inserted some of the water must come out.*

1. How did you learn what the water did?

(NOTE-BOOK.) 1. *I saw it run over.*

Call a fact learned through the senses an *observation.*

* See preface for suggestions in regard to records in Note-book.

In the dictionary you will find *observe* given as formed from the Latin *observare*, meaning *to pay attention to, to watch.* After this is placed the suffix *tion*, meaning *the act of.*

Inf. 2. What is the meaning of the whole word as you get it from its formation?

(NOTE-BOOK.) *Inf.* 2. *From the meaning of the parts, it would mean the act of paying attention to, or watching.*

2. Can you see any connection between this meaning and the sense in which we have used it above?

(NOTE-BOOK.) 2. *The fact learned is the result of paying attention.*

This tracing out the origin of words is called *derivation.*

In this work always try to discover the connection between the original meaning of the word and the sense in which you find it used.

3. How did you learn *what caused* the water to run over in the above experiment?

(NOTE-BOOK.) 3. *I learned it by thinking.*

Call a fact obtained by thinking, or reasoning from other facts, an *inference.*

Give the derivation of this word.

(NOTE-BOOK.) *Inference is formed from the Latin inferre, meaning to bring forward, and the suffix ence, meaning the quality of, the act of, and sometimes the result of, or that which. Here the sense seems to be that which is brought forward by thinking.*

EXPERIMENT 2. (At home.)

Holding an inverted tumbler evenly above a basin of water, push it downward into the water.

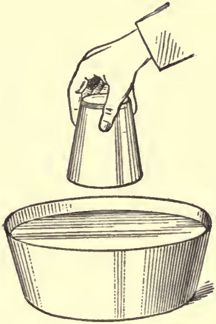

Fig. 1.

Obs. Observe the height of the water under the tumbler.

Inf. 1. What keeps it from rising higher?

Inf. 2. Why does that prevent it from rising?

1. Name three other things that take up room.
2. Does a thought take up room?
3. Can you think of other things which do not?
   Call that which occupies room *matter*.

BODY.

4. Name six different *pieces* of matter.
   Call them *bodies*.
5. What, then, is a body?

SUBSTANCE.

6. Name six different *kinds* of matter.

Call each kind of matter a *substance.*

7. What is a substance ?

Derive *substance.*

Inf. 3. How many bodies can occupy the same space at the same time ?

Call the property of matter by which no two bodies can occupy the same space at the same time *impenetrability.*

Define *impenetrability.*

Derive the term.

Describe experiments showing the impenetrability of matter.

II. DIVISIONS OF MATTER.

MOLECULE, MASS.

EXPERIMENT 3. (At home.)

Break a lump of salt into several pieces.

Dry one small piece thoroughly, and powder as fine as possible in a mortar.

Notice the size of these particles.

Imagine the division to be continued until the smallest particles which can exist by themselves have been formed.

Call these *molecules*.

Thus, the smallest particles of any substance which can exist by themselves are called *molecules*.

Derive *molecule*.

Call any quantity of matter greater than a molecule a *mass*.

Derive *mass*.

1. Name six masses of matter.

COMPOUND.

Each of these molecules of salt is composed of the metal *sodium* and a green gas called *chlorine*.

Let the teacher show a piece of sodium, and prepare a little chlorine by adding sulphuric acid to a little bleaching powder in a test tube or large-mouthed bottle.

Be careful not to inhale much of the chlorine. Sodium should be handled with forceps or dry paper, and kept under petroleum or kerosene.

Obs. Describe sodium and chlorine.

Sodium and chlorine are always combined in *exactly the same proportion* to form salt.

Call a substance which, like salt, has been found to be composed of two or more different kinds of matter combined in definite proportions a *compound.*

Water, alcohol, acids, kerosene, and iron-rust are compounds.

2. Compounds are what kind of substances?

Derive the term.

ELEMENT.

Sodium has never been separated into different kinds of matter. Neither has chlorine.

Call such substances *elements.*

3. What do you understand by "such substances"?

Oxygen, hydrogen, nitrogen, carbon, iron, lead, tin, gold, and silver are some of the common elements.

Derive *element.*

ATOMS.

4. A molecule of salt contains what elements?

Inf. How must the quantity of sodium in a molecule compare with the quantity of salt in the molecule?

Call the smallest particle of matter which can exist combined with other particles an *atom.*

5. What is an atom?

Derive the term.

6. Name the divisions of matter which we have considered.
7. Which of these have you seen?

Inf. 2. Do the others really exist?

SIZE OF MOLECULES.

EXPERIMENT 4. (At home.)

Add a drop of "bluing" to a tumbler of water.

Obs. State the effect.

Inf. 1. What gives the color to the "bluing"?

Inf. 2. What to the water in the tumbler?

Inf. 3. Where are these particles?

Inf. 4. What do you infer in regard to the size of the molecules of coloring matter?

The *odor* of a substance is supposed to be due to small particles of the substance floating in the air and coming in contact with the nerve of smell. A little sachet powder will fill the air with perfume for a long time without undergoing any sensible loss of weight.

Inf. 5. What do you infer from this in regard to the size of the molecules?

III. STATES OF MATTER.

1. LIQUIDS.

EXPERIMENT 5. (At home.)

Put your finger into water, and stir it round.

Obs. 1. Observe the ease with which the finger is moved through the water.

Inf. 1. Make an inference in regard to the movement of the particles of water among themselves.

Remove your finger, keeping the end downward.

Obs. 2. Observe what forms at the end.

Inf. 2. Infer whether the particles tend to separate or to cling together.

1. What two things do you find to be true of the particles of water?
2. Name three other substances of which the same is true.
3. What common name may you give to these substances?
4. What would you say that liquids are? (See question 1, above.)

Derive *liquid.*

2. SOLIDS.

5. Compare wood, iron, and glass with liquids.
   In which of the above points do they agree? (See question 1.)
   In which do they differ?

EXPERIMENT 6. (At school.)

Fasten one end of a stick of sealing wax firmly in a horizontal position. Leaving the other end unsupported, suspend from it a weight of one quarter of a pound.

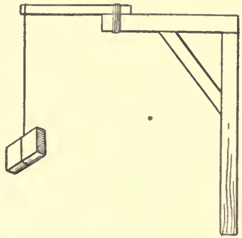

Fig. 2.

Obs. Let it remain for two days, observing the effect from time to time.

What is the result?

Inf. 1. Make an inference in regard to the movement of the molecules among themselves.

Inf. 2. Give a common name for such substances as wood, iron, and wax.

What have you found to be the distinguishing properties of these substances? (See question 5, above, and Inf. 1.)

How would you define solids.

Derive the term.

3. AERIFORM MATTER.

EXPERIMENT 7. (At school.)

Fit two horse-radish bottles with air-tight cork stoppers.

Half fill one bottle with water.

Cut off two pieces of glass tubing an inch longer than the height of the bottles, and one piece about two inches long.

To cut glass tubing make a notch on one side by two or three forward strokes of a triangular file, grasp the tube in both hands with the thumbs against it opposite, on the other side from the notch, and break by pressing out with the thumbs and drawing towards you with the outsides of the hands. Heat the ends of the pieces of tubing in the gas or alcohol flame until the sharp edges are rounded.

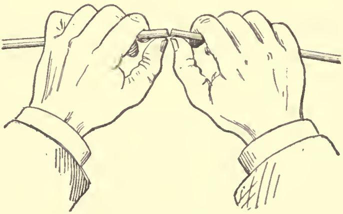

Fig. 3.

With a rat-tail file bore a hole in the stopper of the bottle containing the water, just large enough for the tube to fit air-tight; and push one of the longer tubes through the hole so that it will reach nearly to the bottom of the bottle.

In the same way fit the other two tubes into the stopper of the other bottle, letting them project about a quarter of an inch below the stopper.

Connect the two bottles by a piece of rubber tubing drawn over the ends of the glass tubes which project but little above the stoppers.

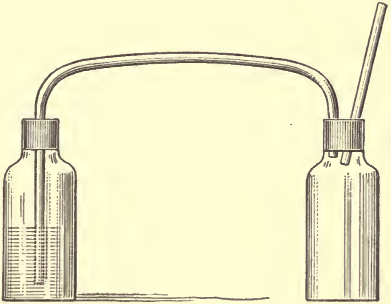

Fig. 4.

Obs. 1. What is in the bottles now?

Taking the end of the projecting tube in the mouth, "draw out" as much air as you can.

Obs. 2. What is the effect?

Inf. 1. Infer the cause of this.

Inf. 2. What tendency of the molecules of air is shown in this experiment?

1. How does air differ from liquids?
2. In what respect is it like liquids?

   Call such matter as air *aeriform matter*.
3. What are its distinguishing properties? (See questions 1 and 2.)

4. Define aeriform matter.

Derive *aeriform.*

5. What other aeriform matter have you seen ?
6. What name is applied to both liquids, and aeriform matter ?

GAS AND VAPOR.

EXPERIMENT 8. (At school.)

Boil a little water in a test tube.

Obs. Notice what is formed, and where it goes.

Inf. 1. What is it formed from ?

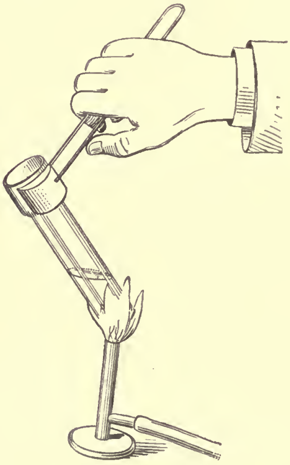

Fig. 5.

Inf. 2. When wet clothing dries where does the water go?

1. Can you see this water in the air?
2. In what state of matter is water ordinarily?
3. In what state of matter is this invisible water in the air?

   Call such aeriform matter *vapor*.
4. How does it differ from air? (See question 2.) Call such aeriform matter as air *gas*.
5. What other gases have you known?

Write a connected description of the different states of matter, showing by illustrations what each is.

IV. CHANGES IN MATTER.

1. CHEMICAL CHANGE.

EXPERIMENT 9. (At school.)

Place a little copper in a test tube.

Add about twice its weight of nitric acid.

Obs. Observe, and state the effect in the liquid, and above the liquid.

Inf. 1. Infer what gives the color to the liquid.

Would copper give it that color? Would nitric acid?

Inf. 2. How many new substances are being formed in the liquid?

1. How does each differ from copper?

2. How does each differ from nitric acid?

Inf. 3. What are they formed from?

Why do you think so?

Inf. 4. Are the molecules of these new substances the same as those of the copper and nitric acid?

3. Why do you think so?

Inf. 5. Are the atoms the same?

Call a change in which the atoms of one or more substances combine in such a way as to form one or more new substances a *chemical change.*

Derive the term *chemical.*

Inf. 6. In the preceding experiment were the copper and nitric acid changed into nothing?

Inf. 7. What became of them?

4. What other chemical changes have you seen?

2. PHYSICAL CHANGE.

1. Were any new substances formed in the first experiment ?
2. How does the ninth differ from this ?

   Call a change in matter in which no new substance is formed a *physical change.*
3. What kinds of changes have occurred in each of the other experiments performed ?

PHYSICS.

Call the knowledge of physical changes *Physics.*

Derive the terms *physics* and *physical.*

Call the knowledge of chemical changes . . . .

Write a connected description of the changes in matter, illustrating by experiments.

V. FORCE.

1. DEFINITION.

Call that which produces, or tends to produce, change *force.*

As to what this cause of change really is, we know nothing. We must infer that there is a cause, and we name it force.

Derive the word *force.*

2. PHYSICAL AND CHEMICAL.

Inf. 1. The cause of a physical change would be called what kind of a force?

Inf. 2. The cause of a chemical change would be called what kind of a force?

It is also called *chemical affinity.*

Derive *affinity.*

1. It acts between what divisions of matter?
2. Physical forces act between what divisions of matter?

3. DIFFERENT FORCES.

a. MUSCULAR FORCE.

EXPERIMENT 10. (At home.)

Lift a chair, and hold it at arm's length.

Inf. 1. What produces this change?

1. By what was the force exerted?

Inf. 2. Infer a name for force so exerted.

2. Give other illustrations of the use of such force.

b. GRAVITATION.

EXPERIMENT 11. (At home.)

Fill a wooden pail with water.

When the water has come to rest scatter a few blocks or chips of wood over its surface.

Obs. 1. Observe any change in the positions of the blocks.

Obs. 2. Let the pail stand for an hour, and observe the positions in which the blocks have come to rest.

Inf. Infer the cause of the change.

Where have you noticed similar results?

EXPERIMENT 12. (At home.)

Hold a brick, or a stone as large as a brick, two or three feet from the ground, and let go.

Obs. State what happens.

Inf. Infer the cause.

EXPERIMENT 13. (At home.)

Place a brick upon the hand.

Obs. 1. Observe the effect.

Inf. 1. Infer the cause.

1. Upon what divisions of matter did the force manifested in the last three experiments act?
2. In what directions with reference to each other did it draw the bodies?

   Call this force *gravitation.*
3. What, then, would you say that gravitation is?

Derive *gravitation.*

GRAVITY.

4. In the last two experiments gravitation acted between what two bodies ?

5. Between the earth and what other bodies *have you found* that this force acts ?

Call the attraction between the *earth* and *bodies on or near its surface gravity.*

Derive the term.

6. What other name applies to this force? (See question 2.)

7. Which is the more definite name ? Why ?

Inf. 2. Infer another name for a force which draws together.

Since it draws *masses* together it is called *molar attraction.*

Derive these words.

Obs. 2. If you fasten a string to a horse-chestnut and swing it so that it moves in the circumference of a circle, what is the effect upon the fingers ?

Obs. 3. If you let go the string, what happens ?

Inf. 3. This shows that a body moving in the circumference of a circle *tends* to move in what kind of a line ?

8. What other evidence of this tendency have you noticed ?

This tendency has been called *centrifugal force.*

9. Describe the tendency.

Derive *centrifugal.*

The earth and other planets move round the sun in nearly circular orbits.

Inf. 4. What prevents them from moving off in straight lines?

c. COHESION.

Inf. 5. What would you call that which holds the *molecules* of a substance together? (See Inf. 2.)

10. This force acts between molecules of the same kind, or of different kinds?

    Call the force which . . . . together *cohesion.*

Derive the word.

d. ADHESION.

EXPERIMENT 14. (At home.)

Insert your pencil in water, and withdraw it.

Obs. Observe the effect upon the pencil.

Inf. Infer the cause.

EXPERIMENT 15. (At home.)

Rub the lead of your pencil across a piece of paper.

Obs. Observe the effect upon the paper.

Inf. Infer what causes this.

1. Are the molecules of lead and paper alike?

   Call the force which holds molecules of different substances together *adhesion.*

Derive *adhesion.*

2. How does it differ from cohesion?
3. In what do cohesion and adhesion agree?

   Hence the term *molecular attraction* is applied to both.

e. HEAT.

EXPERIMENT 16. (At home.)

Hold a piece of wax near the flame of a burning match.

Obs. Observe the effect upon the wax.

Call the force which causes this change *heat.*

f. LIGHT.

EXPERIMENT 17. (At school.)

Moisten a strip of paper four inches long in a solution of silver nitrate.

Shut one half of the paper between the leaves of a book, and leave the other half exposed.

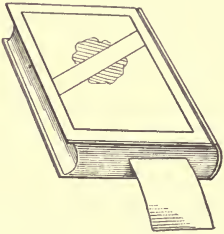

Fig. 6.

Place the book where the sun will shine upon the exposed half of the paper, and leave it there for ten minutes.

Obs. Observe the effect upon each half of the paper.

Inf. Infer what force produced the change.

g. MAGNETISM.

EXPERIMENT 18. (At school.)

Obs. Bring a magnet near to, or in contact with, pieces of copper, iron, zinc, lead, silver, steel, wood, and other substances, and observe the effect.

Inf. Infer what must have produced this effect.

Call this force *magnetism.*

Derive *magnet* and *magnetism.*

h. FRICTIONAL ELECTRICITY.

EXPERIMENT 19. (At home.)

Fold a piece of silk cloth into a pad five or six inches square.

Warm the pad, and also a straight lamp chimney or stick of sealing wax.

Obs. 1. Bring them successively near some small bits of paper, and see if they affect the paper.

Rub the chimney briskly with the silk, and repeat the experiment.

Obs. 2. State the effect.

Inf. 1. Infer the cause.

Inf. 2. Infer how this force was produced.

Call it *frictional electricity.*

Derive these words.

i. VOLTAIC ELECTRICITY.

EXPERIMENT 20. (At school.)

Into a tumbler two thirds full of water pour about one twelfth as much sulphuric acid.

Add as much potassium bichromate as will dissolve. In this solution insert a plate of sheet copper and one of sheet zinc, each about 2 × 5 inches.

Obs. 1. Holding them so that they will not touch each other, observe the surfaces of the metals.

Obs. 2. Touch their outer ends together, and observe any action upon the surface of either or both.

Inf. 1. What kind of change is this?

Remove the plates, punch a hole near the top of each, and connect them by a piece of copper wire 16 inches long, as shown in Figure 7.

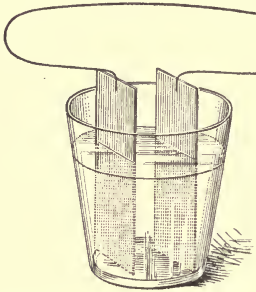

Fig. 7.

Obs. 3. Insert the plates in the solution, and see if there is any action upon the surface of either.

Remove the plates.

Magnetize a large needle or half a knitting needle, by rubbing the end of a magnet from one end of the needle to the other, always in the same direction.

Suspend this needle by a silk thread so that it will balance in a horizontal position.

When the needle has come to rest hold the wire connecting the plates parallel with the needle and just below it; and then just above it.

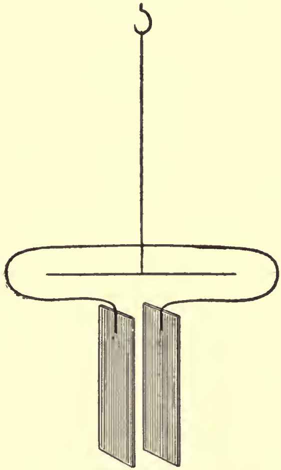

Fig. 8.

Obs. 4. Was the needle affected?

Insert the plates in the liquid in the tumbler, and hold the wire to the needle as before.

Obs. 5. State the effect.

Call the force which produces this change *voltaic electricity*.

Inf. 2. How was it developed? (See Inf. 1.)

Derive the term *voltaic.*

1. Name the different forces which we have been considering.
2. Which of these act upon masses?

Inf. 3. What kind of forces may you call them?

3. Which act upon molecules?

Inf. 4. What kind of forces may they be called?

4. Which tend to bring bodies together?
   Gravitation has also been called *molar attraction.*
5. Which of these forces hold molecules together?
6. What common name have you given to these forces?

Write a connected description of the different forces studied, illustrating them by experiments.

4. CORRELATION OF FORCES.

EXPERIMENT 21. (At home.)

Touch a cent to your cheek.

Rub one side of it briskly against your sleeve for a few seconds, and touch it to the cheek again.

Obs. Observe any change.

Inf. Infer how it was produced.

1. What force was applied in the experiment?
2. What force was developed by it?
3. In what other cases have you noticed that heat was developed by friction?

EXPERIMENT 22. (At home.)

Obs. 1. Examine a common match and see what it consists of.

The substance with which the tip is coated is a preparation containing phosphorus.

Rub the end of the match over a rather rough surface.

Obs. 2. Observe and state carefully what happens.

Note the color of the flame, and any change in color.

Obs. 3. Bring your hand near the flame and observe the effect.

Inf. 1. Infer what force was developed by the rubbing?

1. What change immediately followed the rubbing?

Inf. 2. Infer what force must have caused the new combinations of matter.

Inf. 3. Did the heat aid or hinder the action of this force?

Inf. 4. What force is developed by the action of chemical affinity?

How do you learn this fact?

Inf. 5. What force is made to act by the action of *this* heat?

Inf. 6. How does the amount of heat developed by this chemical action compare with the amount used in starting the action?

2. State the order in which the different forces acted in Experiment 22, and the effect of each.

Inf. 7. In the use of a locomotive to move a train of cars what force acts first in the fire-box?

Inf. 8. What force is produced by this action?

Inf. 9. What effect does the heat in the water of the boiler have upon the train of cars?

Call a force applied through a machine a *mechanical* force.

Derive the term.

3. The heat produced in the fire is here converted into what kind of force?
4. Lightning is the action of what force?
5. When it strikes a building what effect is often produced?

Inf. 10. Infer what force must have been developed in order to produce this effect.

6. What changes of force occur here?

Inf. 11. In producing electric light for towns what forces act, and in what order?

Call this relation of forces by which one force may be converted into another *correlation of forces.*

Derive *correlation.*

Explain from illustrations, in writing, what is meant by correlation of forces.

5. MOLECULAR ATTRACTION.

1. What two forms of molecular attraction have we considered?

Define each.

SOLUTION AND CRYSTALLIZATION.

EXPERIMENT 23. (At school.)

In two thirds of a tumbler of boiling water dissolve as much (powdered) alum as you can.

Suspend a small string over the middle of the tumbler, so that it will reach nearly to the bottom of the liquid.

Place the tumbler where it will not be disturbed, and allow the liquid to cool slowly.

Obs. Observe what forms upon the string, and upon the inside of the tumbler.

Potassium bichromate, copper sulphate, or iron sulphate may be used in place of the alum.

1. What state of matter was the alum?
2. What state of matter was the water?
3. What state of matter did the alum become in the hot water?

   Call such a mingling of a solid with a liquid a *solution.*

The term solution is also applied to a mixture of a gas with a liquid, or to a mixture of two liquids.

Derive the term *solution.*

Inf. 1. What force must have acted to hold the molecules of alum and water together?

Inf. 2. What force must have been overcome in forming this solution?

4. What force was applied to aid the solution?
5. When this force disappeared what happened?

Inf. 3. What force must have acted to bring the molecules of alum together again?

Inf. 4. In this experiment does heat act with cohesion, or in opposition to it?

6. What kind of faces did the solids formed from this solution have?

Call solids having such faces and formed in this way *crystals.*

Define *crystals.*
Derive the term.

Call the process of forming them *crystallization.*

Derive *crystallization.*

CAPILLARY ATTRACTION.

EXPERIMENT 24. (At home.)

In a pan or plate containing a little water place two glass plates vertically, so that, with two of their vertical edges in contact, they will form a small angle.

Obs. 1. Increase and diminish the size of the angle, and observe the height of the water between the plates.

Inf. 1. Infer the cause.

Obs. 2. Oil the plates, and repeat the experiment.

Inf. 2. Observe and infer as directed.

EXPERIMENT 25. (At school.)

Insert small glass tubes of different sizes in water, in mercury, and in other liquids.

Obs. Observe the height of each liquid in the tubes.

Inf. Infer the cause of the difference observed.

1. The attraction manifest in Experiments 24 and 25 is between molecules of what states of matter?
2. What is its effect upon the liquid?

Call this form of adhesion *capillary attraction.*

Describe it.

Derive *capillary.*

ABSORPTION OF GASES.

EXPERIMENT 26. (At school.)

Obs. 1. Observe the odor of dilute ammonia water.

The odor is due to ammonia gas, which is mixed with the water and is gradually escaping from it.

Pour a little of this liquid into a test tube and add half as much powdered charcoal.

FILTER.

Fold a circular piece of filter paper (three or four inches in diameter) upon its diameter, and fold it again upon the radius at right angles to this diameter.

Open it at the circumference so as to make a hollow cone, and insert the apex in the mouth of a horse-radish bottle.

Pour the contents of the test tube into the paper cone.

Obs. 2. Observe what happens.

Call this apparatus a *filter.*

Call the liquid that passes through the paper a *filtrate.*

Obs. 3. Observe the odor of the filtrate and that of the charcoal.

Inf. 1. Infer the cause of the change.

The experiment may be repeated using hydrogen disulphide in place of ammonia.

Inf. 2. What does the charcoal do in these experiments?

Inf. 3. What force acts here?

From this peculiarity charcoal is used as a *deodorizer.*

Derive this term.

Inf. 4. Infer why a drop of oil on paper spreads over the paper.

1. Where does the oil of a lamp burn?

Inf. 5. Infer how it gets there.

6. MOLAR FORCE.

a. IMPULSIVE AND CONSTANT.

1. How does the force with which a bat strikes a ball compare in the length of time which it acts with the force which draws the ball to the ground?

   Call a force which acts only for an instant an *impulsive force.*

Define.

Derive the term.

   Call a force which acts continuously a *constant force.*

Define.

Derive *constant.*

2. What kind of force is the pressure of steam in a boiler ?
3. The attraction of two bodies for each other ?
4. Force applied by a blow ?

b. TENDENCY OF FORCE.

EXPERIMENT 27. (At home.)

Obs. Toss a ball gently upward, and observe carefully any change in the motion.

Inf. 1. What produced the motion ?

Inf. 2. What caused the changes in it ?

1. Does molar force *always* produce motion or change of motion ?
2. Give an instance in which muscular force does not produce either.
3. Give an instance in which gravity does not produce either.

Inf. 3. What is the *tendency* of molar force ?

c. VELOCITY OF MOTION.

1. How fast does a train of cars go ?
2. How fast does a man walk ?

Inf. 1. Call the rate of motion of a body its . . . . .
Derive the term.

We say that a horse goes eight miles an hour.

3. What is an hour ?
4. What is eight miles ?
5. What did we state in giving the velocity of the train of cars ?

Uniform, Variable, Accelerated, Retarded.

6. How do the distances which the earth turns in successive hours compare?

Call such a rate of motion *uniform* velocity.

7. What is uniform velocity?

Derive *uniform*.

8. When a train of cars is getting under way, or when it is just coming to a stop, how do the distances passed in successive seconds compare?

Call a rate of motion at which a body passes over a different distance in each successive unit of time *variable* velocity.

9. Define variable velocity.

Derive *variable*.

10. Define *accelerated* velocity.

Derive the term.

11. Define *retarded* velocity.

Derive *retarded*.

12. Give examples of uniform velocity.

13. Give examples of accelerated velocity.

14. Give examples of retarded velocity.

Inf. 2. What kind of velocity is produced by an impulsive force acting alone?

Inf. 3. By a constant force acting alone?

Inf. 4. By an impulsive and a constant force acting together in opposite directions?

Think of a body thrown upward.

d. MOMENTUM.

EXPERIMENT 28. (At home.)

Roll a marble slowly upon the floor or oil-cloth.

Roll it twice as fast.

Think how much motion of matter there is in a second in the first case, and how much in the second case.

1. Compare the quantity of motion in a second in the first case with that in the second case.

   Call the quantity of motion of a body in a given time its *momentum*.[1]

Derive *momentum*.

Inf. Infer one thing upon which the momentum of a body depends.

EXPERIMENT 29. (At home.)

Roll a small marble, and then roll one two or three times as heavy at the same rate.

1. Compare the movements of matter in a second in those two cases.

Inf. Infer another thing upon which momentum depends.

e. INERTIA.

Inf. 1. Could a moving body ever change its velocity or direction of motion unless acted upon by some force?

[1] The term *momentum* has sometimes been used to mean the force with which a moving body tends to overcome resistance and move on.

Call the inability of a moving body to change its motion *inertia of motion.*

Define.

The term *inertia* is also used in the sense of the *tendency* of a body at rest to remain at rest, or of a body in motion to continue the motion.

Derive *inertia.*

Inf. 2. Call the inability of a body at rest to move *inertia of* . . . .

Define.

A man stood on the bow of a boat when it struck a hidden rock.

Inf. 3. Infer what happened, and why.

Inf. 4. Why is it dangerous to step from a moving carriage or car?

Inf. 5. How may it be done most safely?

Inf. 6. An electric car started suddenly, and many of the standing passengers were . . . .

Inf. 7. Why?

Inf. 8. Why does a train of cars start slowly and acquire speed gradually?

Inf. 9. Why can it not be stopped suddenly?

1. What is the effect when two rapidly moving trains meet upon the same track? Why?
2. In driving a nail with a hammer what is the force as it is applied to the nail?

Inf. 10. How is the dust removed from a carpet by beating?

f. RESISTANCE.

OF THE AIR.

EXPERIMENT 30. (At home.)

Move a fan edgewise quickly through the air.

Obs. Move it at the same rate in the usual way, and observe any difference in the force required.

Inf. 1. Infer what causes this difference.

Call that which hinders motion *resistance.*

Define.

Derive *resistance.*

Call the resistance in this experiment *resistance of the air.*

Inf. 2. It is really due to what property of the air?

OF INERTIA.

Inf. 3. To what is the greater part of the resistance in starting a train of cars due?

Call it *resistance of inertia.*

Inf. 4. What does the amount of this resistance depend upon?

OF FRICTION.

EXPERIMENT 31. (At home.)

Tie one end of a string around a book.

Obs. Holding the other end in the fingers, draw the book by the string slowly and with uniform motion over the carpet, and notice whether any force is required after inertia has been overcome.

Inf. Infer why this force is required.

Call this resistance the *resistance of friction.*

Derive this term.

Of Muscular Force.

EXPERIMENT 32. (At home.)

Obs. Repeat Experiment 31, pressing with the fingers of the other hand slightly against the forward end of the book, and observe any difference in the force required to move the book.

Inf. Infer what this difference is due to.

Of Gravity.

EXPERIMENT 33. (At home.)

Raise the book vertically by the string.

Inf. 1. What is the resistance chiefly due to?

Inf. 2. If the book weighs two pounds and you lift with a force of three pounds, what beçomes of the surplus force which gravity does not resist?

Inf. 3. How much of this surplus will be used up in that way?

Iuf. 4. How, then, does the sum of all the different forms of resistance compare with the force resisted?

Inf. 5. How does the direction of the resistance compare with that of the moving force?

Newton has expressed these facts by saying that *action* and *reaction* are *equal* and *in opposite directions.*

Inf. 6. What can he mean by *action* and *reaction?*

g. MEASURE OF FORCE.

EXPERIMENT 34. (At school.)

Make a spring of No. 22 brass wire by winding it closely upon a pencil.

Cut the string used in Experiment 31 between the book and the end held in the fingers, and fasten the ends thus made to the ends of the spring.

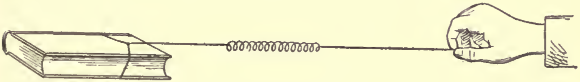

Fig. 9.

Obs. 1. Repeat Experiment 31, and ascertain by a rule how much the spring is stretched.

Obs. 2. Draw the book over the smooth surface of a table, and see how much the spring is stretched.

Inf. 1. Compare carefully the forces used in the two parts of this experiment.

1. What is the *unit* used in the measure of gravity? Other molar forces are measured by the same unit.

EXPERIMENT 35. (At home.)

Make a one-pound, a two-pound, and a five-pound weight, by weighing out the right quantities of pebbles in tin cans.

Lift these weights successively, and note the force required in each case.

1. Compare a force that will sustain one pound with one which will support two pounds; with one which will support five pounds.

h. WORK.

Inf. 1. What forms of resistance must be overcome in drawing a double-runner up hill ?

Call the overcoming of resistance of any kind *work*.

Inf. 2. *a.* How does the work of raising a pound one foot compare with the work of raising it four feet ?

b. With that of raising it ten feet ?

c. With that of raising two pounds two feet ?

d. With that of raising three pounds ten feet ?

1. What two things must be considered in measuring work ?
2. What is the unit of work with which we have compared the work in each of these cases ?

   Call this unit a *foot-pound*.

Define.

3. How many foot-pounds of work in each of the above cases ?

i. POWER.

Inf. 1. Which can do more work in an hour, a horse or a locomotive ?

The *rate* at which an agent can do work is spoken of as its *power*.

Define.

Inf. 2. In measuring power what must we consider besides units of work done ?

One *foot-pound* of work in a *second* is a unit of power.

In measuring the power of agents capable of doing a large amount of work 550 foot-pounds of work in a second is taken as the standard. This is called a *horse-power*.

Define.

An engine of one horse-power is capable of acting through one foot in a second against a resistance of 550 pounds, or of acting through 550 feet in a second against a resistance of one pound.

1. How far can it raise 275 pounds in a second?
2. How far can it raise 1100 pounds in a second?
3. How far can it raise 1100 pounds in ten seconds?
4. How many pounds can a twenty horse-power engine raise ten feet in a second?

j. ENERGY.

Inf. Think how it is that a *moving body*, a *bent* or *coiled spring*, or a *lifted weight* can do work.

Call the ability to do work *energy*.

Define.

Derive the term.

k. COMPOSITION OF FORCES.

From a strip of sheet lead, cut three pieces an inch square, two pieces 1 × 2 inches, two pieces 1 × 3

inches, two pieces 1×4 inches, and two pieces 1×6 inches; and make a hole with an awl through one corner of each piece.

Make a wooden frame two feet long and sixteen inches high, and attach two small pulleys to the top of the frame a foot apart, as shown in Figure 10.

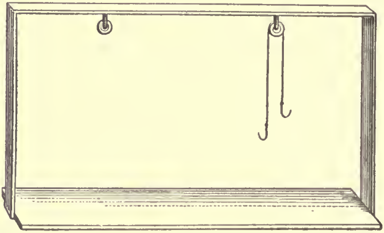

Fig. 10.

Equilibrium.

EXPERIMENT 36. (At school.)

Pass a short string over one of the pulleys and tie a hook made of a bent pin to each end of it.

Hang a strong envelope upon one hook, and upon the other hang an inch lead and a two-inch lead.

Pour into the envelope as much sand as the two leads will balance.

When all the forces acting upon a body balance each other, it is said to be in *equilibrium.*

Derive the term.

Resultant.

1. Do the two leads act in the same or in different lines ?

2. In the same or in opposite directions ?

Obs. Find a single force which will produce the same effect as these two.

Call it a *resultant* of the two.

Define.

Derive *resultant.*

Components.

Call the original forces the *components* of the resultant.

Define. (A force may have more than two components.)

Derive the term *components.*

Two Forces in Same Line.

IN SAME DIRECTION.

Inf. 1. Resultant of two forces acting in same line in same direction equals what ? (See Obs., above.)

Acts where ? and in what direction ?

Suppose a boat is rowed down stream at the rate of four miles an hour, and the current carries it two miles an hour.

Inf. 2. With what velocity does it proceed ?

IN OPPOSITE DIRECTION.

EXPERIMENT 37. (At school.)

Pass the string over the pulley, and hang a two-inch lead on one end and a six-inch lead on the other.

Hang an envelope on the hook with the lighter weight, and pour into it sand enough to produce equilibrium.

Obs. Remove the two lead weights, and find their resultant, and apply it.

1. This is the resultant of what ?

2. It equals what ? acts where ? in what line ?

A boat sails through the water at the rate of eight miles an hour against a current of three miles an hour.

Inf. 1. What is its actual rate of progress ?

A steamer propelled by a force that would carry her ten miles an hour is held back by a wind that, acting alone, would carry her astern at the rate of four miles an hour.

Inf. 2. How long will it take her to go twenty-eight miles ?

Two Parallel Forces.

IN SAME DIRECTION.

EXPERIMENT 38. (At school.)

On the same side of a light wooden bar thirteen inches long place two small screw-eyes twelve inches apart.

On the opposide side of the bar insert three more screw-eyes at intervals of three inches from the first and from each other.

Pass cords from the end screw-eyes over the pulleys, in the frame used in Experiment 36, and balance

Fig. 11.

the bar in a horizontal position by small weights on the cords.

Obs. On one of these cords hang a two-inch lead, and on the other a six-inch lead; and find what weight they will balance, and where it must be placed to keep the bar horizontal.

Inf. 1. From this infer what the resultant must be.

A force of 100 pounds and a force of 200 pounds act in parallel lines in the same direction.

Inf. 2. Their resultant is a force of . . . . pounds acting in the . . . . . direction, in a line . . . . . as far from the line of the greater force as from that of the smaller.

Two Forces at an Angle.

A boat is rowed across a river at the rate of six feet a second, and carried down stream by the current at the rate of three feet a second.

1. Draw a line on paper, starting from a given point *a*, to represent the direction in which the boat would have moved and the distance which the rowing would have carried it in three seconds without any current, and mark the end *b*.

Draw another line, starting from the same point, to show in what direction and how far the current would have carried it without the rowing, and mark the end *c*.

Consider the rowing and the current as acting at the same time.

How far across the river and how far down the river will it have been carried in twenty seconds ?

Mark its actual position at the end of that time *d*.

Draw a line showing the actual path in which the boat has moved.

Connect *d* with *b* and *c* by straight lines.

2. What figure have you drawn ?
3. What does the diagonal represent ?
4. What do the sides *ab* and *ac* represent ?

Inf. Infer how the resultant compares with the sum of the components, and with the difference of the components.

5. How does its direction compare with the directions of the components ?

VI. GRAVITY.

1. Recall *definition* and *derivation* of gravity.

2. CENTRE OF GRAVITY.

EXPERIMENT 39. (At home.)

Suspend a weight from a fixed point by a thread about twelve inches long, with a small loop in the thread just below the point of support.

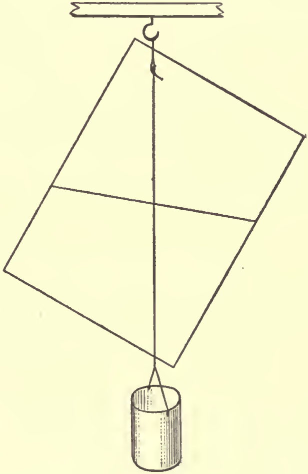

Fig. 12.

Stick a pin through a piece of card-board near one edge, and hang it in the loop so that the thread will be in front of the card-board.

Mark upon the card-board the position of the thread below the loop.

Stick the pin through some other part of the card-board near the edge, hang it in the loop, and mark as before.

Place the intersection of these marks on the point of a pin, and see if it will balance in different positions.

If not, repeat the experiment, taking care to mark the positions of the thread exactly.

Call the point at which a body may be supported in any position its *centre of gravity*.

Define.

3. LINE OF DIRECTION.

Call the line passing through the centre of gravity of a body and the centre of the earth the *line of direction* of the body.

Define.

4. EQUILIBRIUM.

a. OF A BODY SUPPORTED AT ONE POINT.

EXPERIMENT 40. (At home.)

Stick a pin through the card used in Experiment 39, at its centre of gravity, and pin it against a vertical surface so that it will turn easily on the pin.

Obs. 1. In what positions is it in equilibrium ?

Obs. 2. In the same way support the card an inch from the centre of gravity, and find in what positions it is in equilibrium.

STABLE EQUILIBRIUM.

Obs. 3. In what direction from the centre of gravity is the support when the greatest force is required to overturn the body ?

Inf. 1. Why is more force required to disturb the equilibrium with the body in this position ?

A body so supported is said to be in *stable equilibrium.*

Derive *stable.*

UNSTABLE EQUILIBRIUM.

Obs. 4. In what direction from the centre of gravity is the support applied when least force is required to overturn the body ?

Inf. 2. Why is less force required with the support applied there ?

A body so supported is said to be in *unstable equilibrium.*

Derive *unstable.*

NEUTRAL EQUILIBRIUM.

Obs. 5. Where is the support applied when the body is balanced in any position ?

A body so supported is said to be in *neutral equilibrium.*

Derive *neutral.*

b. OF A BODY RESTING ON ITS BASE.

1. In what position is a book in most stable equilibium ?

Inf. 1. In what position of the book will the centre of gravity have to be raised most to overturn it ?

Inf. 2. In what position of the book would the centre of gravity have to be raised least to overturn it?

Inf. 3. Is a tall body more or less stable than a short body? Why? (See Inf. 1 and 2.)

Inf. 4. Is a body with a large base more or less stable than one with a small base? Why?

Inf. 5. Through what point of the base must the line of direction pass that the body may be as stable as possible?

Inf. 6. Will a body stand if the line of direction passes outside the base?

Inf. 7. The stability of a body resting on its base depends upon what?

Inf. 8. Why are legs of chairs and stools made to slant outward?

A young lady placed a step ladder in the position shown in Figure 13, and it stood.

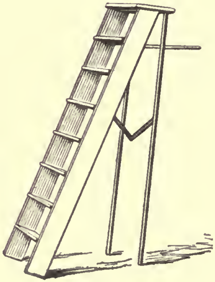

Fig. 13.

Inf. 9. Infer where the line of direction passed with regard to the base.

The young lady proceeded to mount the steps.

Inf. 10. Infer what happened, and why.

5. FALLING BODIES.

Inf. 11. What causes bodies to fall?

1. What kind of a force is gravity?

Inf. 12. Infer with what kind of velocity a body will fall?

EXPERIMENT 41. (At home.)

Obs. Get some one to drop a body from an elevated position, and, standing at a little distance, observe the rate of fall carefully.

1. Does your observation agree with your inference?

6. PENDULUM.

a. DEFINITIONS.

EXPERIMENT 42. (At home.)

By means of a thread suspend a light weight from a fixed point, so that the centre of gravity of the weight will be eighteen inches from the point of support.

Obs. Pull the weight aside; let go, observe the effect, and describe it carefully.

Call a body suspended from a fixed point so as to swing freely a *pendulum*.

Define.

Derive *pendulum*.

Call one swing of a pendulum a *vibration.*
Define.
Derive *vibration.*

b. CAUSE OF VIBRATION.

Inf. Infer what causes a pendulum to vibrate.

c. RATE OF VIBRATION.

EFFECT OF LENGTH OF ARC.

EXPERIMENT 43. (At home.)

Obs. 1. Pull the pendulum three inches aside, let go, and count the vibrations for thirty seconds.

Obs. 2. Pull the pendulum six inches aside, let go, and count the vibrations for thirty seconds.

Inf. Infer whether the rate of vibration is affected by the length of arc through which the pendulum swings.

EFFECT OF WEIGHT OF PENDULUM.

EXPERIMENT 44. (At home.)

Obs. Suspend a heavier weight so as to make a pendulum of the same length, and see how many vibrations it will make in thirty seconds.

Inf. Infer whether the weight of the pendulum affects the rate of vibration.

EFFECT OF LENGTH OF PENDULUM.

EXPERIMENT 45. (At home.)

Obs. 1. Lengthen the pendulum and see how the rate of vibration is affected.

Obs. 2. Make the pendulum four times as long as at first, and see how the rate of vibration is affected.

EXPERIMENT 46. (At home.)

Obs. 1. By trial find a pendulum of such length that it will make one vibration a second.

How long is it?

Obs. 2. Find a pendulum that will vibrate half-seconds.

How long is it?

USE OF THE PENDULUM.

1. How does the number of vibrations made by a pendulum in one minute compare with the number made in any other minute?

2. How then, would you say the pendulum vibrates?

3. By reason of this fact it is adapted to what use?

Describe its use as a metronome.

Derive *metronome*.

USE IN CLOCKS.

EXPERIMENT 47. (At school.)

Wind a clock, and start it. Notice how it goes for a minute or two.

Obs. Remove the hands and face of the clock, and observe how the pendulum is connected with the works.

Inf. 1. What is the tendency of the coiled spring?

Inf. 2. What is the relation of the spring to the works?

Inf. 3. Infer what would happen if there were no pendulum?

Inf. 4. Infer the use of the pendulum.

7. PRESSURE OF LIQUIDS.

a. FACT OF PRESSURE.

EXPERIMENT 48. (At school.)

Over the large end of a small lamp chimney tie a piece of sheet rubber such as may be obtained of a dentist.

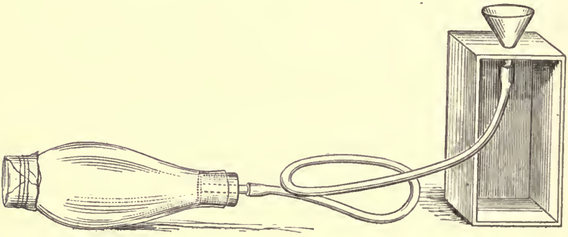

Fig. 14.

Fit a cork stopper water-tight into the small end of the chimney.

Perforate the cork near one side with a rat-tail file, and fit tightly a short glass tube.

Over the end of this tube draw one end of a piece of rubber tubing about two feet long.

Draw the other end of this tubing over the tube of a small tunnel supported by means of a crayon box or stand, as in Figure 14.

Loosen the stopper a little so that air may escape, and pour into the tunnel water enough to fill the chimney, the tube, and the tunnel; and press the stopper in tight.

Obs. 1. Observe the effect upon the sheet rubber.

Inf. 1. Infer the cause of this.

b. DIRECTIONS OF PRESSURE.

Obs. 2. Keeping the sheet rubber at the same distance below the level of the surface of the water in the tunnel, turn the chimney so that it will be horizontal, and observe the effect upon the sheet rubber.

Do not claim to *observe* what you *infer*.

Inf. 2. What causes this?

Obs. 3. Keeping the rubber at the same level, turn the chimney so that the rubber will be upward, and observe.

Inf. 3. Infer the cause.

Inf. 4. In what directions does water at rest press?

c. UPON WHAT PRESSURE DEPENDS.

EXPERIMENT 49. (At school.)

Obs. Slowly lower the chimney farther below the level of the surface of the water, and observe the effect upon the sheet rubber.

Inf. What does pressure of a liquid at rest depend upon? i. e. how does it vary?

EXPERIMENT 50. (At school.)

In the gas or alcohol lamp flame, heat a piece of small glass tubing about two inches from the end, and when it becomes soft draw it out to a point.

When it is cooled, break off the small end of the two-inch piece, so as to leave an opening about one sixteenth of an inch in diameter.

Fit the large end of this tube into the cork stopper in the end of the chimney.

Obs. 1. Fill the chimney, tube, and tunnel with water, and observe what the water does.

Obs. 2. Lower and raise the chimney, and observe the effect.

Inf. Infer the cause of this action.

d. SURFACE OF LIQUID IN COMMUNICATING VESSELS.

EXPERIMENT 51. (At school.)

Remove the short glass tube from the cork, and insert one about two feet long.

Obs. 1. Holding the chimney and this long tube upright, fill the chimney, rubber tube, and tunnel with water, and observe the height of the water in the glass tube.

Obs. 2. Slowly raise and lower the tunnel, and compare the height of the water in the glass tube with its height in the tunnel.

e. WATER WORKS FOR CITIES AND TOWNS.

Describe with diagrams the water works of your city or town, representing the *pumping station, stand-pipe or reservoir*, *mains*, *hydrants*, and *pipes in a house.*

Inf. 1. Where is the presure in the pipes greatest ?

Inf. 2. How high will water rise in the pipes ?

Inf. 3. Where would water be thrown highest from a hose connected with a hydrant ?

f. THE SPIRIT LEVEL.

Examine a spirit level.

Obs. 1. Of what parts does it consist ?

The liquid in the tube is alcohol, and the bubble is air.

Inf. Why is alcohol better than water ?

Obs. 2. When the bubble is in the middle of the tube, what is the position of the case ?

1. How is the level used ?

g. SPRINGS AND WELLS.

What becomes of the water that falls upon the land as rain ?

The portion of it which sinks into the ground works down through soil, loam, sand, or gravel, and comes to a layer of material, $a\ a'$, in the diagram, through which it does not readily pass.

It works its way along the slope of this impervious layer, through the loose material which rests upon it, and may reach the surface at some lower level, as at a'.

Call the water flowing out at the surface a *spring*.

Suppose the water fills the loose material to the level $c\ c'$.

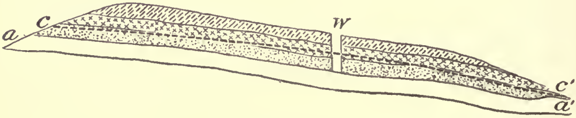

Fig. 15.

Inf. 1. If a hole is dug down through this material, as at w, what will fill the lower part of the hole?

Inf. 2. To what level?

Call such a hole extending down below the level of the water in the earth a . . . . . .

Artesian Wells.

Sometimes a layer of loose material, as $s\ s'$, included between two layers of earth impervious to water, is exposed at the surface along one edge, as

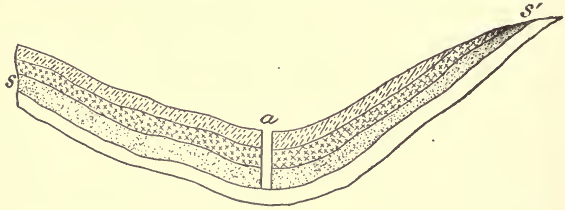

Fig. 16.

at s', and stretches down an extended slope, perhaps for many miles.

The exposed portion of this layer may cover a large area.

What will become of the water which falls upon this exposed portion of the stratum ?

Suppose a hole be bored through the close layer above at some lower point, as at *a*.

Inf. 1. Infer what the effect would be.

Call such a well an *Artesian well.*

Derive this name.

Inf. 2. What force acts to produce springs and wells ?

h. FLOATING AND SINKING.

EXPERIMENT 52. (At school.)

Upon a convenient support four or five feet from the floor hang the spring balance, so that it will not be within four or five inches of a wall.

Upon the hook of the balance hang a quart tin pail, and observe its weight.

Below the pail suspend a pebble a little smaller than the pail and observe its weight.

Set another pail, large enough to contain the pebble, in a basin, and fill this pail just full of water. Holding the balance in the hand, lower it until the pebble is covered with the water.

Obs. 1. Observe what happens to the water and to the spring.

Inf. 1. Infer how large a volume of water is displaced.

Inf. 2. Has the pebble gained or lost in weight by being immersed in the water? How much?

Obs. 2. Remove the pail from the basin, and, again holding the balance so that the pebble is immersed, pour the water from the basin into the empty pail, and notice the effect upon the balance.

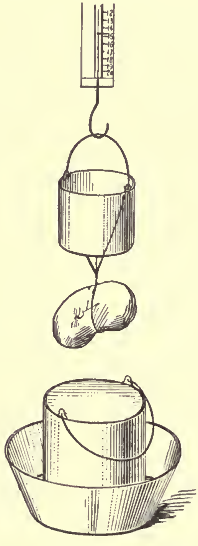

Fig. 17.

Inf. 3. How does the weight of the pebble in water, together with the weight of the water displaced, compare with the weight of the pebble in air?

Repeat this experiment using a mass of iron in place of the pebble.

Inf. 4. How does the loss of weight of a solid immersed compare with the weight of an equal volume of the liquid?

Inf. 5. A solid having the same weight as its own volume of the liquid will lose how much of its weight on being immersed?

Inf. 6. Will it float, or sink?

Inf. 7. If it will float, at what level?

Inf. 8. Will a body heavier than water float in water, or sink?

Inf. 9. Will a body lighter than water float, or sink?

Inf. 10. Will it project above the liquid?

Inf. 11. A body half as heavy as water will float with what part of it above water?

Inf. 12. Since a piece of sheet tin or of iron sinks in water, how can a tin pan or an iron ship float?

i. SPECIFIC GRAVITY.

Of Solids.

Divide the weight of the pebble in air, in the preceding experiment, by the weight of an equal volume of water.

Call the quotient the *specific gravity* of the pebble.

Derive the term.

Find the specific gravity of a mass of iron weighing two or three pounds.

a. Think how you can find the weight of an equal volume of water.

b. Think how you can proceed to find the specific gravity of the iron.

c. Find it.

1. State how to find the specific gravity of solids heavier than water.

Inf. 13. Suppose a body floats with half of its volume under water, what is its specific gravity?

Inf. 14. If it floats with an eighth of its volume under water, what is its specific gravity?

Inf. 15. If a body floats with five sixths of its volume out of water, what is its specific gravity?

A convenient spring balance for finding the specific gravity of small specimens of minerals and metals may be made as follows.

Cut out a piece of board (pine or white wood) about 6 inches square, and another piece about 16 inches long, and $1\frac{1}{2}$ inches wide at one end and 1 inch at the other end.

Nail the wide end of this strip to the middle of one edge of the square, so that it will stand upright with the square as a base, as shown in the figure.

Near the top of this standard insert horizontally a screw-eye of small wire $1\frac{1}{2}$ inches long, with eye opened so as to form a hook.

Make a spring by winding brass wire, No. 25 to 28, close about a pencil, and keeping it wound for a minute or two.

Hang the spring by one end of the coil upon the hook.

Bend the end of the wire at the lower end of the coil into a horizontal position, so that it will project as an index in front of the standard.

Mark off a scale upon this standard from the level of the index downward, by drawing horizontal lines $\frac{1}{16}$ of an inch apart and numbering every fifth line.

By means of a noose of horse hair or fine thread, suspend the specimen from the lower end of the spring, and see how many degrees it stretches the spring, i.e. how many units of weight it has.

Raise a tumbler partly filled with water under the specimen until it is immersed, and thus get its loss of weight in water.

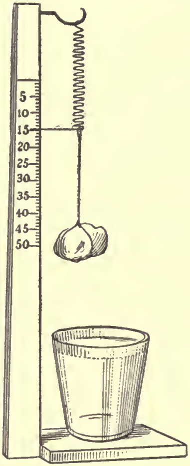

Fig. 18.

Of Liquids.

EXPERIMENT 53. (At school.)

1. Weigh a small-mouthed bottle.
2. Fill it with water and weigh it.
3. Fill it with saturated brine and weigh it.
4. Find the specific gravity of the brine.
5. Find the specific gravity of alcohol, of linseed oil, and of kerosene.

8. PRESSURE OF AIR.

a. FACT OF PRESSURE.

EXPERIMENT 54. (At school.)

Over the mouth of a T. D. clay pipe, tie, air-tight, a piece of sheet rubber.

Obs. 1. Taking the stem of the pipe in the mouth. with the bowl upright, "draw out" through the stem as much air as you can, and observe the effect upon the sheet rubber.

Inf. 1. Infer what causes this effect.

b. DIRECTIONS OF PRESSURE.

Obs. 2. Turn the bowl of the pipe downward, draw out the air, and observe the effect.

Inf. 2. Infer the cause of this.

Repeat this with the bowl in various positions.

Inf. 3. In what directions does the air press ?

c. EFFECTS OF PRESSURE.

EXPERIMENT 55. (At home.)

Fill a tumbler with water, cut a piece of card-board a little larger than the top of the tumbler, and lay it over the top.

With the palm of the hand hold it against the edge of the tumbler without pressing the middle of it in, invert the tumbler, and remove the hand.

Obs. Observe the effect.

Inf. Infer why the water does not fall out.

EXPERIMENT 56. (At school.)

Insert a small glass tube in water, and note the height of the water in the tube.

Place the thumb over the top, and raise it vertically out of the water.

Obs. Observe whether the water remains in the tube.

Inf. Infer the cause.

EXPERIMENT 57. (At home.)

Fill a tumbler with water, invert it under water, and, holding it even, raise it until the mouth is nearly even with the top of the water.

Obs. Observe the height of the water in the tumbler.

Inf. 1. What sustains the water there?

Inf. 2. What force causes the pressure of the air?

BAROMETER.

EXPERIMENT 58. (At school.)

By means of a short piece of rubber tubing, connect the tube of a small glass tunnel with one end of a heavy glass tube 33 or 34 inches long, and closed at the other end.

Fill the tube with mercury.

If there are air bubbles in the tube, remove them by inserting a slender iron wire.

Holding the finger firmly over the end of the tube,

so that no mercury can run out, invert the tube, and insert the open end of it in a cup of mercury.

Obs. 1. Notice the height of the mercury in the tube.

Inf. 1. Why does it not all run out of the tube?

Inf. 2. Why does it not entirely fill the tube?

Obs. 2. Measure the height of the mercury in the tube above the surface of the mercury in the cup.

It is found by experiment that the height of the column of mercury is *not affected* by the *size* of the tube, but *varies slightly* for *all tubes* at different times.

Inf. 3. What does the height of the mercury column depend upon? (See Inf. 1 and 2.)

Inf. 4. What does the variation in the height of the mercury indicate?

Thus the height of the mercury column becomes a *measure of the atmospheric pressure.*

Fig. 19.

For this use the tube is attached to a case with a graduated scale at the top to indicate the height of the mercury column in inches; and the whole apparatus is called a *barometer.*

Describe it, and derive the name.

EXPERIMENT 59. (At school.)

Place the barometer where it will not be disturbed, and note the changes in the height of the mercury and the changes in the weather for a few weeks.

Obs. What correspondence in these changes can you discover?

Inf. What inferences in regard to the weather can you make from changes in the barometer?

Pumps.

Lifting Pumps.

EXPERIMENT 60 (At school.)

Into an even glass tube fit a piston with a rod a little longer than the tube.

Holding the tube in the left hand, push the piston through the tube so that it will be even with the end of the tube.

Obs. Holding this end steadily under water, slowly raise the piston, and observe the effect in the tube.

Inf. What causes this?

If you have a glass lifting pump, or can buy one, use it. If not, a good one may be made by careful work.

To make a Lifting Pump.

Fit two small screw-eyes with rather long screws into the end of a spool 1 inch or $1\frac{1}{16}$ inches in diameter, as shown in Figure 20.

Cut out a piece of sheet rubber $\frac{1}{2} \times \frac{3}{4}$ of an inch; lay one end of this upon the flat surface of a block of pine $\frac{1}{2} \times \frac{1}{2} \times \frac{3}{16}$ of an inch, and fasten it to the block by a single small tack in the centre. (See Figure 20.)

Lay this block, rubber-side down, over the hole in the end of the spool between the screw-eyes; and with two small tacks fasten the projecting portion of the rubber to the end of the spool, so as to form a little valve opening from the spool and covering the hole in the spool when closed.

Get a piece of pine 10 inches long and $\frac{1}{2}$ inch square at one end, and at the other end $\frac{1}{2}$ inch thick and wide enough to fill the space between the screw-eyes.

Place the wide end of the rod between the screw-eyes, and fasten it by small screws passing through the screw-eyes, taking care to have the end of the rod far enough from the spool to allow the valve to open at least $\frac{1}{4}$ of an inch.

Round off the rod with a knife, and wind upon the spool enough twine to a little more than fill it.

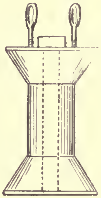

Fig. 20.

Fig. 21.

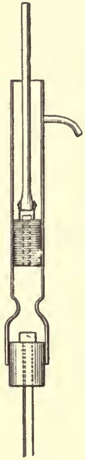

Fig. 22.

Call this apparatus the *piston* of your pump.

Select a lamp chimney such as is shown in Figure 21, of the same diameter throughout the straight part.

To test the evenness of chimneys fit the piston into them and work it carefully up and down, noticing whether the fit is equally close throughout.

Fit tightly a cork into the large end of the chimney.

Perforate this cork with a rat-tail file, and fit a glass tube 8 or 10 inches long into it water-tight, as shown in Figure 22.

Make a valve covering the top of this tube like the valve in the top of the piston.

Insert the cork into which the tube has been fitted in the large end of the chimney.

With a triangular file make a hole through the side of the chimney about 2 inches from the top, then with a rat-tail file round out the hole so as to make it elliptical, and insert in it a short piece of rubber tube for a spout.

EXPERIMENT 61. (At school.)

Having made sure that the piston and the cork are tight, take the chimney in the left hand and the piston rod in the right, and inserting the glass tube below the surface of the water, carefully work the piston up and down.

Obs. 1. Observe the position of each valve as the piston is raised, and as it is lowered.

If no change is observed, work the piston faster, and notice carefully.

Inf. 1. Infer the cause of the changes.

Obs. 2. Observe the change in the water.

Inf. 2. Infer the cause of this change.

NOTE. — To say that the water is "drawn up," or "sucked up," is not giving any *cause.*

If a pipe 33 feet or more in length, closed at one end and open at the other, be filled with water, and, with the open end kept under water, the closed end be raised until it is brought to a vertical position, it has been found that the water will continue to fill the pipe to the height of about 32 feet above the level of the water outside of the pipe.

Inf. 3. Infer what keeps the water up to that height.

Inf. 4. Why does it not sustain a higher column of water?

Inf. 5. About how high should you think water could be raised with a lifting pump?

Is it ever necessary to raise water higher than that?

FORCE PUMP.

TO MAKE A FORCE PUMP.

Fit a rod about 10 inches long into a spool 1 inch in diameter, as in Figure 23. Wind the spool full of twine, and select a lamp chimney of even bore, as for the lifting pump.

Fig. 23.

Fit the bottom of the chimney tightly with a firm cork, and fit the cork with a tube and valve, as in the lifting pump.

Fit tightly a firm cork into a horse-radish bottle.

Connect the lower part of the chimney with the bottle by a glass tube, bent as shown in Figure 24, and fitted tightly into the stoppers.

Over the end of this tube in the bottle place a valve like that in the chimney.

Make another hole in the cork in the bottle and fit into it tightly a glass tube 5 or 6 inches long, bent as shown in the figure, and drawn out to a small size at the end *b*, Figure 24.

EXPERIMENT 62. (At school.)

Having made sure that the piston, corks, and tubes are all tight, hold the chimney in the left hand, insert

the tube *a* under water, and work the piston carefully with the right hand.

Obs. 1. Observe the action of each valve and the movement of the water as the piston is raised and as it is pressed downward.

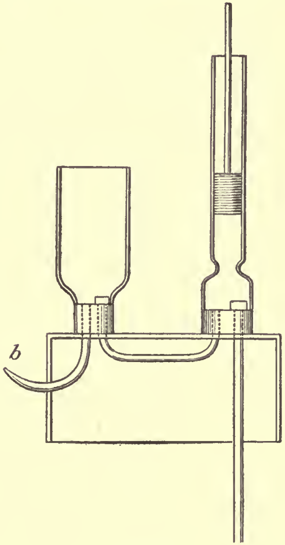

Fig. 24.

Inf. 1. Infer the cause of each change observed.

Obs. 2. What is in the upper part of the bottle? Call the bottle an *air-chamber*.

Inf. 2. Of what advantage is it?

Inf. 3. What kind of pump is used at a pumping station?

1. What do fire-engines for throwing water consist of?

Write a connected description of each kind of pump, illustrating by drawings.

VII. SIMPLE MACHINES.

1. LEVERS.

a. DEFINITIONS.

LEVER.

EXPERIMENT 63. (At home.)

Place a pencil or rule upon a book so that one end of it will project about 3 inches beyond the edge of the book.

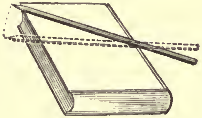

Fig. 25.

By raising and lowering the ends of the pencil, turn it about the edge of the book as a fixed support.

Call a bar so arranged a *lever*.

Define.

Derive the term.

FULCRUM.

Call the support upon which it turns the *fulcrum* of the lever.

Define.

Derive *fulcrum*.

LOAD AND POWER.

EXPERIMENT 64. (At home.)

Place another book upon the projecting end of the lever, and press down with the fingers upon the other end.

Obs. Observe the effect.

Call the second book the *load* of the lever.

Call the force applied to support the load the *power.*

1. In the above experiment what was the position of the fulcrum with reference to the load and the power?
2. Use your pencil as a lever with the load between the power and the fulcrum.
3. Use it as a lever with the power between the load and the fulcrum.

b. RELATION OF POWER TO LOAD.

EXPERIMENT 65. (At school.)

Insert a small screw-eye in the middle of a light wooden bar 13 inches long.

Suspend the bar by this screw-eye from the middle of the frame used in Experiment 36.

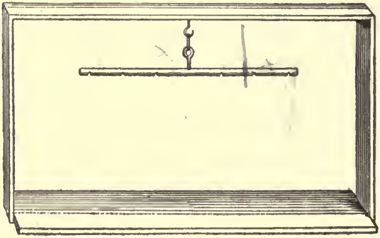

Fig. 26.

If the bar does not balance in a horizontal position, whittle down the heavier arm until it does.

On the under side of this bar cut little notches 2, 4, and 6 inches from the screw-eye towards each end.

Bend one end of a six-inch lead weight into a hook, and hang it as a load upon the bar, so that the middle of the end of the lead will be at a notch 2 inches from the fulcrum.

Obs. 1. Find what power applied at the same distance from the fulcrum will balance this load.

Obs. 2. Find what power applied twice as far from the fulcrum will balance the load.

1. Compare it with the load.

Obs. 3. Find what power applied three times as far from the fulcrum will balance the load.

2. Compare it with the load.

Inf. How does the power required to balance the load vary as the distance of the power from the fulcrum increases?

Obs. 4. Find what power in each of the above positions will raise the load.

Obs. 5. How do the distances moved by the power and load in each of the above positions compare?

When the power required to balance a load is half as great as the load, the distance which it passes in moving the load is . . . . . . as great as that passed by the load.

EXPERIMENT 66. (At school.)

Obs. 1. Find what load placed 2 inches from the fulcrum a power of 2 units applied 2 inches from the fulcrum will balance.

Obs. 2. Applied 4 inches from the fulcrum, it will balance what load 2 inches from the fulcrum?

Obs. 3. Applied 6 inches from the fulcrum, it will balance what load 2 inches from the fulcrum?

EXPERIMENT 67. (At school.)

Obs. Place the load twice as far from the fulcrum as in the last experiment, and see how the power required at any point to balance it is affected.

c. APPLICATIONS.

CROW-BAR.

Describe the crow-bar and its use.

STEELYARD.

Show where the fulcrum is in the steelyard.

Where the load is applied.

Where the power is applied.

How the weight of the load is shown.

2. WHEEL AND AXLE.

a. CONSTRUCTION.

The wheel and axle consists of two connected cylinders of different diameters turning upon a common axis, as shown in Figure 27.

The larger cylinder is called the *wheel,* and the smaller one the *axle.*

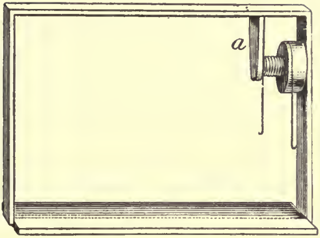

Fig. 27.

The wheel and axle may be made as follows : —

Get a turner to turn for you in one piece two cylinders, each 1 inch long, and one 1 inch and the other 3 inches in diameter, as shown in Figure 28.

At the inner end of the smaller cylinder drive a large gimp tack, allowing the head to project a little.

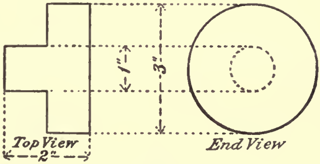

Fig. 28.

In the middle of the opposite side of the larger cylinder drive a small gimp tack.

Make a small hole with an awl in the axis of the cylinders at each end.

Cut out a piece of board 4 inches long, and 3 inches wide at one end and 1 inch at the other. This piece is marked *a* in Figure 27.

Place this piece in position, as shown in the figure, $2\frac{1}{4}$ inches from the end of the frame, and fasten it with screws through the top of the frame.

With an awl make a horizontal hole half an inch above the middle point of the lower end of this piece, and another hole in the same line with this, in the end of the frame.

Place the wheel and axle in position, and fasten it by inserting wire nails through the holes in the frame into the ends of the cylinders.

If it does not turn easily pull out the wire nails and make the holes in the frame a little larger.

b. RELATION OF POWER TO LOAD.

Tie a string 12 inches long to the tack in the wheel, and another to the tack in the axle.

In experimenting, let these strings draw around the wheel and axle in opposite directions.

EXPERIMENT 68. (At school.)

Obs. 1. Hang a load of 6 units upon the string on the axle, and find what power applied to the string on the wheel will balance it.

Obs. 2. Find what power will raise it.

Obs. 3. In moving the load 1 inch the power moves how far?

1. The load is applied how far from the axis?

2. The power is applied how far from the axis?

Inf. 1. The axis of the wheel and axle corresponds to what in the lever?

Inf. 2. The radius of the axle in this experiment corresponds to what in the lever?

Inf. 3. The radius of the wheel corresponds to what in the lever?

In the above experiment the power was applied . . . . times as far from the axis as the load, and a

power . . . as great as the load was required to balance it.

Inf. 4. How does the relation of power to load in the wheel and axle compare with the relation of power to load in the lever?

Inf. 5. How far can a load be moved with one application of the lever?

Inf. 6. How far with one application of the wheel and axle?

Inf. 7. What advantage has the wheel and axlé over the lever?

Inf. 8. For what uses is the lever better adapted?

EXPERIMENT 69. (At school.)

Place a load of 3 units upon the wheel.

Obs. 1. Find what power applied on the axle will balance it.

Obs. 2. Find what power will move it.

Obs. 3. In raising the load 6 inches how far does the power move?

1. How do these results compare with those obtained with the lever?

c. APPLICATIONS.

What uses of any form of wheel and axle have you seen?

Write a composition upon the *Uses of the Wheel and Axle,* illustrating the various forms by drawings.

3. PULLEYS.

a. DESCRIBE.

Examine one of the pulleys in the frame which we have used, and tell what it consists of.

Fixed Pulley.

Call a pulley which remains in the same place when in use a *fixed pulley*.

Movable Pulley.

Call a pulley which changes its place when in use a *movable pulley*.

A good set of pulleys is desirable. If these are not to be had, brass pulleys carefully selected from such as may be found at any hardware store, and at many country stores, will do.

To adapt these for use as movable pulleys wind one end of a piece of $\frac{1}{16}$-inch wire 8 inches long about the shaft just below the pulley. Bend the wire over the pulley, as shown in Figure 29, wind it down around the shaft, and bend the end into a hook.

Fig. 29

b. RELATION OF POWER TO LOAD.

In Fixed Pulleys.

EXPERIMENT 70. (At school.)

Draw a pliable string over a fixed pulley.

Fasten a load of 6 units to one end of the string.

Obs. 1. Find what power applied at the other end will balance it.

Obs. 2. Find what power will raise it.

Inf. Why is a greater power required to raise a load than to balance it?

EXPERIMENT 71. (At school.)

Pass the cord over three fixed pulleys, as shown in Figure 30.

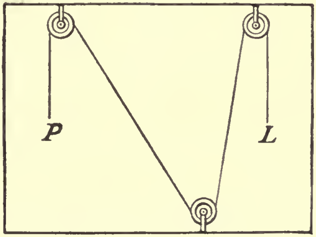

Fig. 30.

Hang a load upon one end of the cord.

Obs. Find what power applied at the other end will balance it.

Inf. Infer what power will balance any load when acting through a cord passing over any number of fixed pulleys.

In Combinations of Fixed and Movable Pulleys.

EXPERIMENT 72. (At school.)

Fasten one end of the string to the top of the frame.

Draw the other end under a movable pulley and over a fixed pulley, as indicated in Figure 31.

Fasten to the string a weight which will balance the weight of the movable pulley.

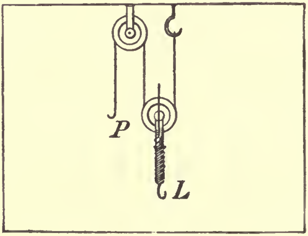

Fig. 31.

Hang a load of 2 pounds on the movable pulley.

Obs. 1. Find what power will balance it.

1. Compare the power and load.

Obs. 2. The movable pulley is supported by how many parts of the cord?

EXPERIMENT 73. (At school.)

Support the movable pulley by three parts of the cord, as shown in Figure 32.

Obs. 1. Balance the weight of the movable pulley, and find how the power which will balance a load, compares with the load.

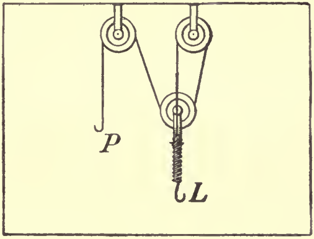

Fig. 32.[1]

Obs. 2. In raising the load how do the distances passed by the power and load compare?

c. USE OF PULLEYS.

Inf. 1. Of what use are fixed pulleys?

Inf. 2. What advantage is there in the use of a combination of fixed and movable pulleys?

Write an illustrated account of the ways in which you have seen pulleys applied.

[1] The fixed pulleys *should* be near enough together to make the parts of the cord draw vertically.

4. INCLINED PLANE.

Get a piece of board 6×24 inches.

Fasten a pulley in the middle of one end of it, as shown in Figure 33.

Place the board upon a table with the pulley projecting 3 inches beyond the end of the table.

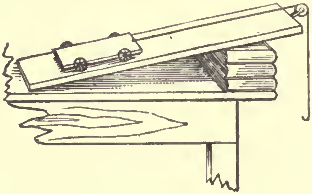

Fig. 33.

Raise the end containing the pulley 4 inches higher than the other end of the board, and support it with books placed under it.

Call the top of this board an *inclined plane.*

a. RELATION OF POWER TO LOAD.

EXPERIMENT 74. (At school.)

Upon this plane place a toy car or carriage with a string fastened to it and passing over the pulley.

Obs. 1. Let go the string, and observe the effect.

Balance the car by a weight upon the string.

Place upon the car a can or box of pebbles weighing 3 pounds.

Obs. 2. Find what power applied at the end of the string will balance this load.

1. How does it compare with the load?
2. How does the height of the plane compare with the length of the plane?

Inf. Infer why the power required is less than the load.

EXPERIMENT 75. (At school.)

Raise the end of the inclined plane 4 inches higher; and repeat the experiment, comparing the power with the load and the height of the plane with its length.

b. USE.

1. Where have you seen inclined planes used for raising loads?

Inf. Of what advantage are they?

5. SCREW.

It is well for the school to own a small jack-screw or bench-screw. If that is not practicable, one may be borrowed of some mechanic or building mover.

1. Turn the screw partly out of the nut, and examine it. What is its general shape?
2. What is there upon the outside of this cylinder?

Call this spiral projection the *thread* of the screw.

3. Notice the upper and lower surfaces of the thread as they wind around the cylinder.

Are they level, or inclined?

What do they form?

4. Remove the screw and examine the inside of the nut.

What do you find for the thread of the screw to fit into?

Figure 34 represents a jack-screw as it would appear if the front half of the upper part of the nut could be removed, showing a vertical section of the nut and the front of the screw.

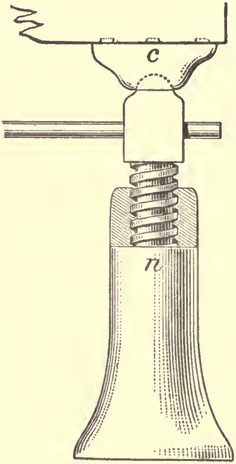

Fig. 34.

5. What does the screw rest upon?
6. What does the under side of the thread slide over when the screw is turned?

See if you can raise a load with a jack-screw. Explain fully by diagram how it is done.

6. WEDGE.

Examine a wedge.

1. Compare it with the inclined plane.
2. For what have you seen it used?
3. In its use is the load moved over the wedge?
4. What is moved?
5. How is it moved?

APPLICATIONS OF THE SIMPLE MACHINES.

1. Which of these machines have you seen used in raising loads to the upper stories of buildings?
2. A door key belongs to which of these classes of machines?
3. Which machines have you seen used for raising and lowering the wicks of lamps?
4. Which would you use for splitting wood?
5. Which is used in moving a building along the street?
6. What other simple machine is used in working a jack-screw?
7. What machine would you use in loading a barrel of oil upon a truck?
8. What machines have been used for raising "the old oaken bucket" from the well?
9. In which of the simple machines is the resistance of friction least?
10. Can any machine furnish energy?

Write an explanation of the *advantages in the use of simple machines,* giving examples and illustrating by diagrams. Show that:

1. They enable us to do slowly *heavier* work than we could do without them, or to do light work *more rapidly* than we could without them.
2. They enable us to use a force at a more convenient point and in a more convenient direction than we could otherwise use it.
3. They enable us to employ other forces than our own in doing work.

VIII. HEAT.

1. SOURCES OF HEAT.

EXPERIMENT 76. (At home.)

Obs. Hold the back of your hand in the sunshine for a minute, and then in the shade, and notice the difference.

Inf. What is one source of heat?

EXPERIMENT 77. (At home.)

Repeat Experiment 21.

Inf. What is another source of heat?

EXPERIMENT 78. (At home.)

Touch a nail to your cheek.

Hammer one end of it upon an anvil for a few seconds, and touch it to the cheek again.

Obs. Observe the change.

Inf. 1. Infer a third source of heat.

In our study of *Correlation of Forces* we noticed two other sources of heat.

1. What are they?
2. Name the sources of heat which we have considered.

Inf. 2. From which of these sources do we get most heat?

Inf. 3. From which do we get the next greatest supply?

2. EFFECTS OF HEAT.

a. EXPANSION.

(1) OF SOLIDS.

EXPERIMENT 79. (At home.)

Bend one end of a wire 10 inches long into a ring just large enough so that a marble will not drop through it.

Fig. 35.

Obs. 1. Heat the ring hot, and see if the marble will drop through.

Inf. 1. Infer the cause.

Inf. 2. What is one effect of heat?

Derive the term *expansion.*

Obs. 2. Cool the ring, and see if the marble will drop through.

Inf. 3. Infer the cause of this.

1. Give other instances in which you have noticed that heat expands solids.
2. In laying the rails of a railroad what allowance is made on account of this fact?
3. Do you know of any uses made of this fact in the arts?

(2) OF LIQUIDS.

EXPERIMENT 80.

Fill a large test tube with cold water.

Insert a stopper into which has been fitted a small

glass tube, so that the water will rise in the tube above the stopper.

Heat the test tube gently.

Obs. 1. Observe the effect on the water.

Fig. 36.

Inf. 1. What causes this?

Obs. 2. Cool the test tube, and observe.

Inf. 2. Infer the cause of this change.

EXPERIMENT 81. (At home.)

Warm a thermometer bulb.

Obs. 1. Observe the mercury in the tube.

Inf. 1. Infer the cause of the change.

Obs. Inf. 2. Cool the bulb, observe, and infer.

1. Describe the thermometer, telling what parts it consists of, describing each, and telling how it works.
2. Give other instances in which you have noticed that heat expands liquids.

(3) Of Gases.

EXPERIMENT 82. (At school.)

Fill the apparatus used in Experiment 80 with air, insert the glass tube beneath the surface of water, and warm the test tube.

Obs. What is the effect?

Inf. What causes this action?

1. What effect of heat is shown in Experiments 79, 80, 81, and 82?

b. CHANGES IN STATES OF MATTER.

Liquefaction.

EXPERIMENT 83. (At home.)

Heat a little ice in a tin can or cup.

Obs. State the effect, and give a name to the change.

Derive the name.

Inf. What would be the effect if this heat were given out from the water?

The change of a liquid to a solid is called *solidification.*

Derive *solidification.*

EXPERIMENT 84. (At school.)

Heat a little lead in an iron spoon.

Obs. 1. Observe the change.

Obs. 2. Allow the lead to cool, and observe the change.

1. Give other instances in which heat changes the state of matter.

Effect of Melting on Adjacent Bodies.

EXPERIMENT 85. (At home.)

In a tin can mix ice, broken into small pieces, with about half its weight of salt.

Obs. 1. Watch the change for a few minutes.

Obs. 2. Then insert your finger in the mixture, and note the temperature.

Into a small test tube pour a few drops of water.

Insert it in the mixture, and leave it for a few minutes.

Obs. 3. Observe the effect on the water in the test tube.

Inf. 1. Infer the cause of this change.

Inf. 2. Infer the effect of melting upon adjacent bodies.

1. What use is made of this fact?

Inf. 3. What effect does the melting of ice and snow have upon the temperature of the air?

Vaporization.

Boiling.

EXPERIMENT 86. (At school.)

Half fill a test tube with water, and heat it carefully by holding it obliquely in the flame for 5 minutes.

Obs. 1. Observe what rises from the tube, and the quantity of water left in the tube.

Inf. Infer what change in the state of matter was produced.

· Call this change *vaporization.*

Derive the term.

Obs. 2. Describe carefully the process as it occurs in this experiment.

What is formed within the liquid? Rapidly? Or slowly?

Call this process . . . .

NOTE. — Some pupils may try additional experiments to determine the boiling points of different liquids, and what the boiling point of any liquid depends upon.

EVAPORATION.

EXPERIMENT 87. (At home.)

Place a *little* water in a shallow tin plate, and heat it gently, without boiling, for half an hour.

Obs. Observe what forms, and the quantity of water remaining.

Inf. Infer what change is taking place.

1. How does the process differ from boiling?

Call it *evaporation.*

Derive the name.

NOTE. — Some pupils may investigate the influences which affect evaporation.

EFFECT OF VAPORIZATION ON ADJACENT BODIES.

EXPERIMENT 88. (At school.)

Place a drop of water on a piece of shaving.

On the drop rest a thin watch crystal with a few drops of ether in it.

With the mouth about 8 inches from the ether, blow steadily across its surface until it has all evaporated.

Obs. Observe the effect upon the water under the crystal.

Inf. 1. Infer the cause of this change.

1. How does sprinkling the floor or the street affect the temperature of the air?
2. How does a summer shower affect the temperature?

Inf. 2. Why?

Explain the manufacture of artificial ice.

Condensation,

EXPERIMENT 89. (At home.)

Obs. Vaporize some water, hold a piece of cold glass in the escaping vapor, and observe the effect.

Inf. Infer the cause of this.

1. What new change in the state of matter occurs in this experiment?

Name the change *condensation.*

Derive the name.

Dew, Dew Point, Frost, Clouds, Rain, Hail, Snow.

EXPERIMENT 90. (At school.)

Half fill a tin fruit can with water at a temperature of about 60 degrees.

Place a chemical themometer in the water, and add small bits of ice gradually until moisture begins to collect on the outside of the can.

Call this moisture *dew*.

Call the temperature at which it begins to form the *dew point*.

Inf. 1. Infer the cause of the deposit.

Inf. 2. Account for the dew on the grass.

Inf. 3. Account for *frost*.

Inf. 4. If cold air meets warm air, what is the effect upon the warm air?

Inf. 5. Upon the moisture in the air?

Inf. 6. Infer how *rain* is formed; *hail*; *snow*.

3. TRANSFER OF HEAT.

a. RADIATION.

EXPERIMENT 91. (At home.)

Hold your hand for a few seconds near a hot stove or any heated body.

Obs. Observe the effect upon it.

Inf. Infer the cause of this.

EXPERIMENT 92. (At home.)

Obs. Hold the hand in various directions from the heated body, and observe the effect.

Inf. Infer in what directions heat passes from heated bodies.

EXPERIMENT 93. (At home.)

Obs. Placing the hand in the same positions as before, hold a sheet of paper between it and the heated body, and observe the result.

Inf. 1. Infer in what kind of lines heat passes from heated bodies.

Inf. 2. Call this passage of heat from a heated body *radiation.*

Derive the term.

Call the body from which it passes a *radiator.*

Derive *radiator.*

Describe the use of *fire screens.*

NOTE. — Some pupils may investigate the radiating powers of rough and smooth surfaces.

b. CONDUCTION.

EXPERIMENT 94. (At school.)

To a small iron rod about 16 inches long stick 4 or 5 marbles along one side with wax, placing one 3 inches from the end, and the others at intervals of 2 or 3 inches.

Hold the end of the rod in the flame as long as any of the marbles stick

Obs. State the result.

Inf. 1. Infer the cause.

Call this passage of heat through a body *conduction.*

Derive the name.

GOOD AND POOR CONDUCTORS.

EXPERIMENT 95. (At school.)

Repeat the last experiment, using a slate pencil in place of the iron rod.

Compare the rate at which the heat passes through the pencil with that at which it passed through the iron rod.

Call the pencil a *poor conductor,* and the rod a *good conductor.*

Derive *conductor.*

Uses of Poor Conductors.

EXPERIMENT 96. (At home.)

Keep a block of oak wood, of pine wood, and of iron, a roll of cotton cloth, of woollen cloth, and of silk cloth, and a thermometer, near together for a few hours in a room where the temperature does not change much.

Obs. 1. Then test the temperature of these bodies with the thermometer, keeping it on each for a few minutes.

Obs. 2. Touch them successively to the cheek, and see if they all feel equally warm.

Inf. 1. Infer the cause of the differences.

Inf. 2. Why is clothing necessary?

Inf. 3. What is the best material for clothing?

1. Mention other uses of poor conductors.

Water as a Conductor.

EXPERIMENT 97. (At school.)

Take a test tube nearly full of water, and, holding it by the lower part, heat it just below the surface of the water until the water begins to boil.

Obs. Observe the temperature of the lower part of the tube.

Inf. Infer what kind of a conductor water is.

Air also is a poor conductor.

What use is made of this fact in constructing houses and refrigerators?

Weight of Hot and Cold Water.

EXPERIMENT 98.

Fill a small can with cold water, and balance it on a scale pan.

Pour out the cold water and fill with hot.

Obs. Place the can on the scale pan, and compare its weight with that of the can of cold water.

Inf. Infer the cause of this difference.

c. CONVECTION.

EXPERIMENT 99. (At home.)

Take a cake pan two thirds full of water, and mix a little fine sawdust with it.

Heat it gently in one place by a flame below.

Obs. Observe the effect in the water.

Inf. 1. How can you explain this movement?

Call this mode of distributing heat *convection*.

Derive *convection*.

Inf. 2. Explain how ocean currents are produced.

EXPERIMENT 100. (At school.)

Fit a broken test tube about 4 inches long with a stopper.

Into this fit a piece of glass tubing (*b c* in Figure 37), 4 inches long.

Bend another piece of tubing, 15 inches long, as shown in Figure 37, *a b*, and fit it into the stopper so that it will reach one inch above the other tube.

Connect these tubes at *b* by a piece of rubber tubing.

Set a crayon box upon one side, and place another box upon this in the same position.

Cut slots in the edges of these boxes for the tubes to pass through, so that the test tube may rest upon the upper box.

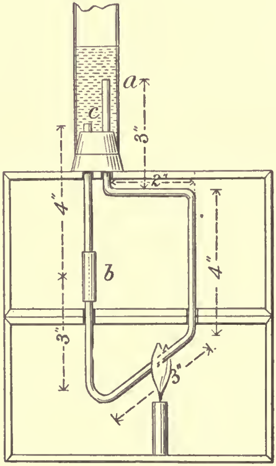

Fig 37.

Pour water slowly into the test tube until it is nearly filled, and add a little fine sawdust.

Heat the slanting portion of the tube with a candle flame.

Obs. Observe any movement of the water.

Inf. Explain what causes it.

1. Explain by diagram the *heating of buildings by hot water.*

Some pupil may construct simple hot-water heating apparatus of glass tubing.

2. Explain by diagram the *furnishing of hot water in a house* from a boiler connected with kitchen range.

Some pupils may construct simple apparatus illustrating this subject.

DRAUGHTS.

EXPERIMENT 101. (At home.)

Hold a lamp chimney over a lamp or gas flame with the left hand, and with the right hand hold a strip of very thin paper one quarter of an inch below the level of the bottom of the chimney, and move it under the chimney on the same level.

Obs. 1. Is the paper affected?

Fig. 38.

Obs. 2. In the same way hold the paper over the top of the chimney and observe.

Inf. Explain the cause of this.

Call this current of air a *draught.*

EXPERIMENT 102. (At home.)

Obs. See if you can detect any draught in the flue of an oil stove, by testing with thin paper at the base and at the top of the flue.

Inf. 1. How is it produced?

Inf. 2. Infer the cause of the draught through a stove and up the chimney.

1. Describe the draught about a hot stove.

Inf. 3. Explain how it is caused.

2. Describe *heating by furnace,* representing the furnace, cold-air box, and furnace pipes by diagram.

Winds.

EXPERIMENT 103. (At home.)

Hold a lighted match at the top, and then at the bottom, of a doorway between a warm and a cool room.

Obs. Observe the direction in which the flame points in each position.

Inf. 1. Infer the cause.

Inf. 2. Infer how these draughts are produced.

Inf. 3. Infer how winds are produced.

Inf. 4. Explain the cause of land and sea breezes.

Inf. 5. Explain the cause of the trade winds.

4. LATENT HEAT.

EXPERIMENT 104. (At school.)

Half fill a small flask with water.

Insert a chemical thermometer, and heat the water to the boiling point.

Obs. 1. Note the temperature.

Obs. 2. Boil 2 or 3 minutes, and see if the temperature rises after it gets to boiling.

Inf. 1. Infer what becomes of the heat applied.

Call it *latent* heat.

Derive *latent.*

EXPERIMENT 105. (At school.)

Transfer the thermometer to a can containing two or three times as much cold water as the flask.

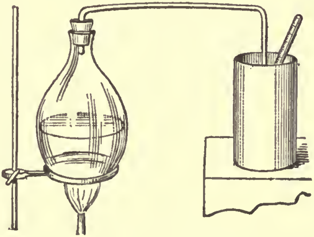

Fig. 39.

Close the flask with a perforated stopper into which has been fitted tight a bent glass tube reaching over into the can of water.

Boil the water in the flask 5 minutes.

Obs. 1. Observe the quantity of water in the flask and in the can, and the temperature of the water in the can.

Do you think the water in the flask has been growing hotter?

Obs. 2. Open the flask, and test it.

Inf. 1. What became of the heat applied?

Inf. 2. What became of the vapor formed?

Inf. 3. What became of the latent heat when this vapor was condensed?

Inf. 4. Explain by diagram the process of *heating by steam.*

Some pupils may construct apparatus illustrating this subject.

EXPERIMENT 106. (At school.)

In one test tube place some fine ice or snow, and in another an equal weight of water.

Obs. 1. Notice the temperature of each.

Obs. 2. Insert both in a can of hot water until the ice is nearly melted, and observe the temperature of each.

Inf. 1. Infer the cause of the difference.

Inf. 2. If no heat were absorbed as latent heat in melting, how long would it take the deepest snow or the thickest ice to melt?

Make a topical outline of these lessons on heat.

Write upon some of the topics.

b. BALANCED BAR.

By heating soften one end of a piece of sealing wax about 2 inches long, and stick it upright upon the centre of a tin box-cover 2 or 3 inches in diameter.

Heat the eye of a needle, and insert it upright in the top of the sealing wax.

With sealing wax, stick a triangular bit of tinfoil on each end of a curved splinter of wood about 6 inches long, and balance it on the point of the needle.

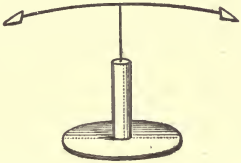

Fig. 44.

Use this balanced bar as an *electroscope;* i. e. to indicate the presence of electricity.

EXPERIMENT 118. (At home.)

Obs. Excite the lamp chimney and bring it near one end of the balanced bar, and observe the effect.

3. KINDS.

EXPERIMENT 119. (At school.)

Obs. 1. Excite the lamp chimney and hold it near the pith-balls for two or three minutes, and observe what happens.

Obs. 2. Try the same with the sealing wax.

EXPERIMENT 120.

Let one pupil excite the lamp chimney and another the sealing wax, and hold them for a minute or two about an inch apart, with the pith-balls between them.

Obs. Observe what happens.

Inf. How can you account for this action of the pith-balls?

EXPERIMENT 121.

Repeat the last two experiments, using the balanced bar instead of the pith-balls.

Call the electricity excited in the lamp chimney *positive* (+), and that excited in the sealing wax *negative* (−).

EXPERIMENT 122.

Find what kind of electricity is excited in the silk pad, and what kind in the flannel pad.

4. LAW.

EXPERIMENT 123.

Bend a wire 12 inches long into the shape shown in Figure 45, and suspend it by a silk thread.

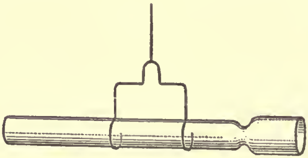

Fig. 45.

Let one pupil excite a lamp chimney and another a second one.

Obs. 1. Lay one of the chimneys upon the wire hooks, bring the other near one end of this, and observe the effect.

Obs. 2. Repeat this experiment, using two sticks of sealing wax in place of the chimneys.

Obs. 3. Repeat, using one chimney and one stick of sealing wax, and observe the effect.

Inf. Infer how bodies charged with the same kind of electricity affect each other, and how those charged with unlike electricities affect each other.

5. CONDUCTION.

CONDUCTORS AND INSULATORS.

EXPERIMENT 124. (At school.)

Lay a piece of glass tubing 1 foot long across the top of a tumbler so that one end of it will come within about one eighth of an inch of one end of the balanced bar.

Obs. 1. Touch the excited chimney to the end of the tube remote from the electroscope, and see if the bar is affected.

Obs. 2. Try the excited sealing wax in place of the chimney.

EXPERIMENT 125. (At school.)

Repeat Experiment 124, using a hard-wood foot rule in place of the glass tube.

EXPERIMENT 126. (At school.)

Repeat, using your lead pencil.

Repeat again, using a key.

Inf. 1. Infer an explanation of the facts observed in Experiments 124 to 126.

Call the action of electricity over a body *conduction.*

Call a body over which electricity acts a *conductor,* and one over which it does not act an *insulator.*

Derive these terms.

Name the conductors and insulators which you have found in these experiments.

Inf. 2. Infer why glass bottles are used in the electroscopes.

Inf. 3. Infer why the pith-balls fly off after contact with an electrified body, and why they repel each other.

Inf. 4. Infer the use of lightning rods.

6. INDUCTION.[1]

EXPERIMENT 127. (At home.)

Support a cylindrical tin box, or can, with the cover on, horizontally upon a dry tumbler, so that one end of the can will be within a quarter of an inch of the bar electroscope.

Bring the excited chimney or sealing wax near the other end of the can, without contact.

Obs. Observe the effect upon the electroscope.

[1] It may be best to omit this topic with classes in grammar schools.

Inf. Infer how this effect can be produced.

Call the development of electricity in a body by the approach of an electrified body, without its coming near enough for a spark to pass, *induction.*

Derive the term.

See what other bodies you can induce electricity in.

See if you can decide what kind of electricity is manifest on the end of the can toward the electroscope. (Recall Experiment 123.)

Obs. and *Inf.* 2. Is there any electricity at the other end?

Obs. and *Inf.* 3. Of what kind is it?

Inf. 4. Infer the first effect of bringing an excited body near an insulated body.

Inf. 5. In view of this, infer why the pith-balls and the bar are attracted to an excited body.

XI. VOLTAIC OR CURRENT ELECTRICITY.

1. VOLTAIC ELEMENT.

EXPERIMENT 128.

Repeat Experiment 20.

Call this apparatus a *Voltaic element.*

1. What does it consist of?

2. HOW PRODUCED.

Inf. Infer how the electricity was produced in the above experiment.

3. EFFECTS.

The effects and applications of electricity are too numerous and varied to be considered, even in the briefest way, in these Lessons. They form a subject for investigation in the latter part of the High School course.

But we will recall briefly two or three effects which we have already noticed.

a. MAGNETIC.

1. What effect of Voltaic electricity have you already observed?

EXPERIMENT 129. (At school.)

Wind about 30 feet of insulated No. 22 copper wire around a small rod of soft iron 5 or 6 inches long, and connect the ends with the plates of the Voltaic element.

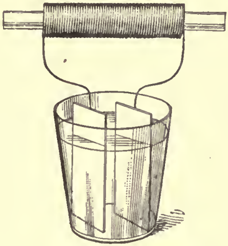

Fig. 46.

Obs. 1. Bring bits of iron near one end of the iron rod, and observe the effect.

Obs. 2. Bring them near the other end, and observe.

Inf. 1. Infer what the rod has become.

Inf. 2. Infer how this change was produced.

Obs. 3. Separate one end of the wire from the plate, and see if the rod retains its magnetism.

Obs. 4. Hold the end of the wire to the plate, and see if the rod is now a magnet.

Obs. 5. Touch a very small tack to the rod, separate the wire from the plate, and see how long the tack is held.

Inf. 3. How long does the rod continue a magnet after the connection between the plates is broken?

Call the iron rod an *electro-magnet.*

Pupils are now prepared to examine and describe the *key* and *receiver* of the telegraph, and the *electric bell* and *press-button.*

The key and press-button are used to make and break connections; and the receiver, or sounder, and the "bell" are applications of electro-magnets.

The construction and working of the telegraph and the electric bell may be described by the pupils in writing.

1. What two effects of Voltaic electricity have you learned?

b. THERMAL.

EXPERIMENT 130. (At school.)

Cut the connecting wire of a Grenet battery, and twist around the ends a piece of fine platinum wire so that there will be about one inch of it between the ends of the copper wire.

Obs. Lower the zinc plate, and test the temperature of the platinum wire.

Inf. Infer how the change has been produced.

c. LUMINOUS.

1. How are incandescent electric lights produced?
2. What other luminous effects of electricity have you noticed?

Prepare a topical outline of these lessons in Electricity, and write upon some of the topics.

XII. SOUND.

1. HOW PRODUCED.

EXPERIMENT 131. (At home.)

Strike one tine of a pitchfork a sharp blow, not too hard.

Obs. Notice what the tine does, and what you hear.

EXPERIMENT 132.

Obs. Pull a piano string a little to one side, let it go, and observe as in the last experiment.

EXPERIMENT 133.

Strike a call bell, and hold a pencil lightly against one edge of the bell.

Obs. Observe the effect as before.

Fig. 47.

Inf. 1. Infer why the pencil moves.

Inf. 2. From these experiments infer what sound is due to.

2. TRANSMISSION OF VIBRATIONS.

a. THROUGH WOOD.

EXPERIMENT 134. (At home.)

Hold a lath horizontal, with one end resting lightly against the panel of a door.

Make a tuning-fork vibrate, and press the end of its handle against the free end of the lath. (A steel table-fork will do.)

Obs. Observe where the sound seems to come from.

Inf. Infer how the vibrations reached the door.

b. THROUGH A STRING.

EXPERIMENT 135. (At home.)

Punch a little hole through the centre of the cover and bottom of a cylindrical tin box.

From the outside insert one end of a string 10 or 12 feet long through the hole in the cover, and the other end through the hole in the bottom. Tie knots in the ends to keep them from pulling out. Let one person hold the open end of the box to his ear, and another person hold the cover far enough away to straighten the string, and sounding the tuning-fork (or table-fork), touch the handle to the box cover.

Obs. 1. The one holding the box to the ear report the effect.

Obs. 2. Where did the sound seem to come from ?

Inf. Infer how the vibrations reached the box.

c. THROUGH THE AIR.

EXPERIMENT 136. (At home.)

Lay a piece of writing paper over the mouth of a tumbler, leaving an opening half an inch or less in width, and trim off the outside of the paper so that it will not project more than half an inch beyond the edge of the tumbler.

Press the paper down against the tumbler, and sprinkle a little fine sand on it.

Obs. Sing a strong, full tone, and, slowly raising and lowering the pitch, watch the sand upon the paper.

If the sand is not affected, change the size of the opening slightly, and repeat until it is affected.

Inf. 1. Infer how this effect is produced.

Inf. 2. Infer how the vibrations reached the paper.

In the ear is a little membrane, stretched over a bony framework, and forming the "drum" of the ear, with which the air comes in contact.

Inf. 3. Infer how it will be affected when objects near us are made to vibrate.

These vibrations continuing, reach the auditory nerve, and the sound is heard.

1. What have you observed that would indicate at what rate sound is transmitted through air?

Plan an experiment which will show approximately the velocity of sound in air.

3. VIBRATING STRINGS.

a. LOUDNESS OF TONES.

EXPERIMENT 137. (At school.)

Stretch a violin string over a *sonometer*.

Derive *sonometer*.

With the finger press the string a little to one side, and then let it slip.

Obs. 1. Observe the effect.

Press the string farther to one side, and let it slip.

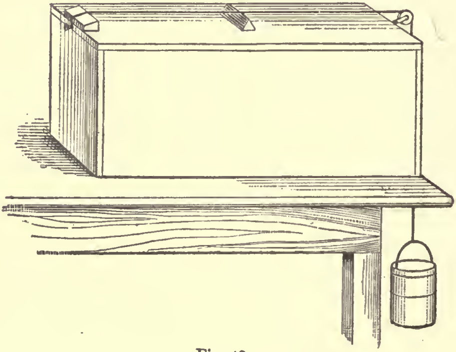

Fig. 48.

Obs. 2. Notice the distance which the string vibrates, and the loudness of the tone.

Obs. 3. Press the string still farther, and observe.

Call the distance through which particles vibrate the *amplitude* of vibration.

Derive *amplitude.*

Inf. Infer what the loudness of a tone depends upon.

Any strong string rubbed with beeswax will do for these experiments.

If a sonometer cannot readily be procured, get a soap-box with a thin, close bottom (Ivory-soap boxes are good), and invert it upon a table.

Insert a screw in the middle of one end, and a pulley in the middle of the other end.

On the top of the box above the screw fasten a block, cut so that the inner edge will be a little higher than the outer edge, as shown in Figure 48.

Make another block in the form of a triangular prism, so that when laid upon one side it will be 1 inch or more in height.

Fasten one end of the string to the screw, and pass the other end over the pulley.

The string may be stretched by the hand or by weights.

b. PITCH OF TONES.

EXPERIMENT 138. (At school.)

Stretch a lighter or a heavier string than was used in the last experiment with the same force (weight), and repeat the experiment.

1. Compare the tone of this string with that of the other.

Inf. Infer whether light strings or heavy ones give higher tones.

EXPERIMENT 139. (At school.)

Obs. Place the movable block at the end next to the pulley, stretch the string with a weight, sound the string, and notice the pitch of its tone.

Move the block inward so as to shorten the vibrating string, and repeat the experiment.

1. Compare the pitch of the tone with that of the tone of the longer string.
2. Shorten the vibrating string more, and repeat the experiment.

Inf. Infer how the tone is affected by the length of the string.

EXPERIMENT 140. (At school.)

Sound a string 16 inches long, and then one 8 inches long and stretched with the same force.

Compare the tones.

EXPERIMENT 141. (At school.)

Stretch a string slightly with the hand.

Obs. 1. Sound it, and observe its pitch.

Obs. 2. Stretch it a little harder, and repeat the experiment.

Obs. 3. Stretch it still harder, and repeat.

Inf. Infer how the tone is affected by increasing the stretching force of the string.

EXPERIMENT 142. (At school.)

Stretch a string 8 or 10 inches long with a force of 1 pound.

Sound the string, and note its pitch.

Stretch the string with a weight of 4 pounds, and repeat.

1. Compare the pitches of these tones.

2. What **three** things have we learned affect the pitch of tones produced by vibrating strings?
3. What strings give high tones?
4. What strings give low tones?
5. How are the strings of a piano varied to produce the different tones desired?
6. How are pianos tuned?

Repeat experiments 139–142, noticing carefully the *rate of vibration* in each case, and see if you can decide what the pitch of a tone really depends upon.

4. VIBRATING COLUMNS OF AIR.

EXPERIMENT 143. (At school.)

Get or make an organ-pipe with one glass side, *a b*, as shown in Figure 50.

An organ-pipe may be made from a straight lamp chimney, by filing a hole at the lip, *l*, as shown in Figure 49.

Fig. 49.

But great care is necessary to get it tight and not break the chimney.

Obs. Blow in at the mouthpiece, and observe the effect.

EXPERIMENT 144. (At school.)

Draw a piece of rubber tubing from 16 to 24 inches long over the mouthpiece.

Cut out a piece of writing paper a little smaller

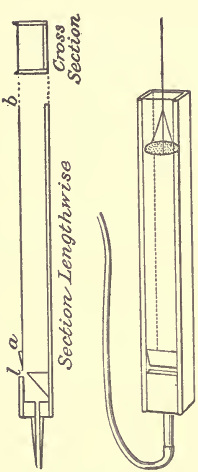

Fig. 50. — Organ Pipe.

Fig. 51.

than the interior of a cross section of the organ-pipe, and suspend it by a thread.

Scatter a little fine sand upon the paper, and, holding the pipe vertically with the open end upward, so that you can see through the glass side, sound the organ-pipe by blowing through the rubber tube.

Slowly lower the sanded paper into the sounding pipe, and carefully watch the sand.

Obs. What do you observe?

Inf. Infer the cause.

As the air is forced into the organ-pipe, it strikes the lip (*l*, Figure 50), and thus obstructed, it issues from the opening in rapid puffs. The pulsations, thus produced, are transmitted to the column of air within the pipe, and cause it to vibrate.

EXPERIMENT 145. (At home.)

Blow across the mouth of a small bottle so as to produce a tone, and notice its pitch.

EXPERIMENT 146. (At home.)

Blow across the mouth of a larger bottle, and compare the pitch of its tone with that of the tone of the smaller bottle.

EXPERIMENT 147. (At home.)

Obs. 1. Pour a little water into the larger bottle, "sound" it, and compare its tone with that of the "empty" bottle.

Obs. 2. Add more water, and observe how the tone changes.

Inf. Infer how the tone of an organ-pipe is affected by the length of the pipe.

EXPERIMENT 148. (At school.)

Obs. Close the outer end of the organ-pipe air-tight, sound it, and compare its tone with that of the open pipe.

Inf. Infer what kind of organ-pipes produce high tones, and what kind produce low tones.

Write a composition upon the *pitch of tones*, deducing the facts from experiments.

Make a topical outline of the lessons on sound.

XIII. LIGHT.

1. SOURCES.

Name some bodies which originate light.

Call such bodies *luminous bodies.*

Derive *luminous.*

Mention some bodies which do not originate light.

Call such bodies *non-luminous bodies.*

Derive *non-luminous.*

Call a body which receives light from other bodies and reflects it an *illuminated body.*

Derive the term.

1. All light comes originally from what kind of bodies?
2. Name the natural sources of light.
3. Name the chief artificial sources of light.

The profitable study of light requires a *porte lumière* and arrangements for darkening the room.

The windows may be darkened by wide curtains of dark cambric, pinned close over the window-frames, or by shutters made by tacking strong opaque paper over wooden frames made to fit the window-frames.

A *porte lumière* may be bought for about $5.00; or one suitable for these experiments *may* be made at an expense of about $0.50.

To make a Porte Lumière.

Get a piece of pine board 9 inches wide, and as long as the width of a window on the south side of the school-room.

On one side of this board mark out a circle 6 inches in diameter, with its centre ½ inch above the central point of the board.

Saw it out with a compass-saw as marked.

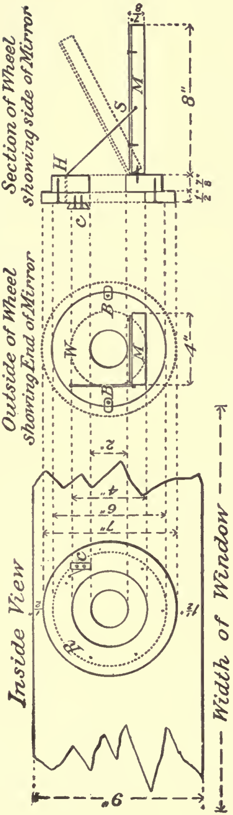

Fig 52.—Porte Lumière.

If necessary, even the edge of this circular piece so that it will turn as a *wheel* in the hole.

In the centre of this wheel bore or cut a round hole 2 inches in diameter.

From $\frac{1}{2}$ inch board cut a ring (R, Figure 52) 7 inches in diameter on the outside and 4 inches inside.

With $1\frac{1}{4}$ inch wire nails fasten this ring to one side of the wheel, so that its rim will project beyond the rim of the wheel $\frac{1}{2}$ inch all round.

Cut out a piece of pine board 4×8 inches (M, Figure 52).

To one side of this fasten a piece of looking-glass, $3\frac{1}{2} \times 7\frac{1}{2}$ inches, by small screws, placed so their heads will lap over the edge of the looking-glass

With a suitable hinge and rather long screws hang this mirror to the wheel in the position shown in Figure 52, so that the mirror may be raised against the wheel.

In one edge of the mirror, $3\frac{1}{4}$ inches from the wheel, insert a small screw (S), letting the head project.

Raise the mirror against the wheel, and with a brad awl make a hole (H) through the wheel opposite the screw in the edge of the mirror.

To the screw fasten one end of a string about 18 inches long, and pass the other end through the awl hole.

Upon the ring, a little below and at the right of the awl hole, by means of screws fasten a small cleat (c) to hitch the string to. Thus the mirror may be held at any angle desired.

Of hard wood make two buttons (B, B) about $1\frac{1}{4} \times \frac{5}{8} \times \frac{1}{4}$ inch, and fasten each with a screw to the wheel, as shown in the figure.

Turn these buttons so that they will not project beyond the rim of the wheel, place the wheel in the board, and fasten it by turning the buttons.

Place the *porte lumière* under the lower sash of a window on the sunny side of the room, and adjust it — by turning the wheel and increasing or diminishing the angle of the mirror — so that it will throw the light squarely and horizontally into the room.

For experiments with small lenses a smaller opening for the admission of light may be needed A hole of the right size may be cut in a piece of cardboard and the cardboard tacked or pinned over the hole in the wheel.

Derive *porte lumière*.

2. TRANSMISSION.

a. MEDIUM,—TRANSPARENT; TRANSLUCENT.

EXPERIMENT 149. (At school.)

With a porte lumière throw some sunlight into a darkened room.

Obs. Can you see the light?

Call that through which it passes a *medium.*

Derive the term.

EXPERIMENT 150. (At school.)

Obs. Hold a piece of window-glass in the path of the light, and observe how much of the light passes through the glass.

1. How much of it passes through the air?

Call the glass and the air *transparent media.*

Derive *transparent.*

EXPERIMENT 151. (At school.)

Obs. Place colored glass, also thin paper, in the path of the light, and observe how much light passes through.

Call such bodies as the colored glass and thin paper *translucent media.*

Derive *translucent.*

1. Name other transparent media.
2. Name other translucent media.
3. How much light will pass through a piece of inch board or a book?

Call these *opaque* bodies.

Derive *opaque.*

b. RAY; *c.* BEAM.

EXPERIMENT 152. (At school.)

Strike together two erasers containing crayon dust along the path of light.

Obs. 1. Observe in what kind of lines the light passes.

Call a single line of light a *ray*.

Derive the term.

1. Are there many or few rays of light thrown into the room by the porte lumière?

Obs. 2. How do these rays compare in direction?

Call a collection of parallel rays a *beam* of light.

d. PENCIL OF LIGHT.

EXPERIMENT 153. (At school.)

Place a double convex lens (see page 139) in the beam of light, and render the path of rays beyond the lens visible by crayon dust.

Obs. Observe the relative direction of the rays beyond the lens.

Call a collection of rays converging to the same point or diverging from the same point a *pencil of light.*

The first is called a *converging* pencil.

The second is called a *diverging* pencil.

Derive *pencil, converging* and *diverging.*

e. IMAGE BY SMALL APERTURE.

EXPERIMENT 154. (At school.)

Bore a hole about half an inch in diameter in one end of a soap-box without cracks, and cover the hole with a piece of tinfoil.

Prick a hole in the tinfoil with a pin.

Invert the box over a lighted candle in a darkened room, and hold a sheet of white paper as a screen before the hole in the tinfoil.

Obs. 1. Observe what forms on the screen.

Inf. 1. See if you can think out and show by diagram how this is formed.

Obs. 2. Bringing the screen near the box, and removing it gradually, observe the effect upon the image.

Inf. 2. See if you can explain the effect by diagram.

EXPERIMENT 155 (At school.)

Through a hole from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in diameter admit light from without into a darkened room, and have a large screen or light wall on the side of the room opposite the hole.

Obs. Observe the result.

f. SHADOW, UMBRA, AND PENUMBRA.

EXPERIMENT 156. (At home.)

Before a lamp flame in a darkened room hold an opaque body smaller than the flame.

Hold a white screen (paper) just beyond the opaque body, and gradually move it farther away.

Obs. Observe the appearance on the screen.

Inf. See if you can explain the appearance by diagram.

Call the space from which light is shut off by an opaque body a *shadow*.

Call the space from which all the light is shut off the *umbra*.

Call the space from which a part only is shut off the *penumbra*.

Derive these terms.

g. ECLIPSE OF THE MOON.

Is the moon a luminous or an illuminated body?

Where does its light come from?

Is the earth transparent or opaque?

What must there be on the side of the earth away from the sun?

Is the earth larger or smaller than the sun?

What must be the form of the earth's umbra?

What must be the form of the earth's penumbra?

Explain how an eclipse of the moon is produced.

h. ECLIPSE OF THE SUN.

Describe the umbra and penumbra of the moon.

Explain how an eclipse of the sun is produced.

i. VELOCITY OF LIGHT.

It has been found that light passes across the earth's orbit in 16 minutes 36 seconds.

The average distance of the earth from the sun is thought to be about 93,000,000 miles.

How far must the light travel in a second?

j. REFLECTION OF LIGHT.

EXPERIMENT 157. (At school.)

By a porte lumière throw a beam of light into a darkened room, and place a mirror in its path.

Render the path of the light visible by crayon dust.

Obs. Observe and state the effect of the mirror upon the light.

Call this turning back rays of light in regular order *reflection.*

Derive the term.

A mirror is what kind of a surface?

What does it do with light?

LAW OF REFLECTION.

Think of a perpendicular to the mirror at the point where the light strikes the mirror.

Call the angle which the rays falling upon the mirror make with this perpendicular the *angle of incidence.*

Derive *incidence.*

Call the angle which the reflected rays make with the perpendicular the *angle of reflection.*

Compare the angle of incidence with the angle of reflection.

Diffused Light.

EXPERIMENT 158. (At school.)

Obs. Place a piece of rough paper in the path of the rays, and see if the light is reflected regularly.

Call light thus scattered by a rough surface *diffused* light.

Derive *diffused*.

Image of a Point by a Plane Mirror.

EXPERIMENT 159. (At home.)

Hold the point of your pencil in front of a plane mirror.

Obs. Observe and describe the location of the image of the point, as seen from any position.

Is the image in front of the mirror, or behind it?

How far?

Where with reference to a line perpendicular to the mirror and passing through the point of the pencil?

Image of an Object by a Plane Mirror

EXPERIMENT 160. (At home.)

Hold any object before a plane mirror.

Obs. Observe and state the position of the image of each point of the object.

When you look in a mirror, the image of your right eye forms which eye of the image of your face?

Images by Two Parallel Plane Mirrors.

EXPERIMENT 161. (At school.)

Cut out a piece of board in the form of a quadrant with a radius of 10 inches.

Along one of the sides saw two parallel scaths (*a* and *b* in Figure 53) $\frac{1}{4}$ of an inch deep and 4 inches apart; and three other scaths (*c*, *d*, and *e* in the figure), making angles of 30, 60, and 90 degrees respectively with the scath *a*.

In the parallel scaths place two pieces of looking-glass, 2 by 6 inches, facing each other.

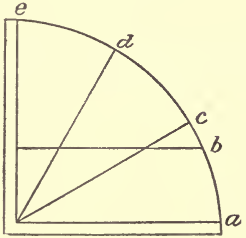

Fig. 53.

Obs. Place a piece of crayon between these mirrors, and see if you can see more than one image of it. How many?

Where are they?

Images by Two Plane Mirrors at an Angle.

EXPERIMENT 162. (At school.)

Obs. On the same board arrange the mirrors at angles of 30, 60, and 90 degrees, and find how many images can be seen from one position with the mirrors at each of these angles

Concave Mirror, Principal Focus, Focal Distance, Centre of Curvature.

EXPERIMENT 163. (At school.)

Place a concave mirror in the path of a beam of light in a darkened room, so that the light will strike perpendicularly at the centre of the mirror.

Obs. Render the path of the reflected light visible by crayon dust, and describe the direction of the rays.

Draw a diagram showing how the light is reflected.

Call the point through which all the reflected rays pass the *principal focus* of the mirror.

Derive *focus.*

Call its distance from the mirror the *focal distance* of the mirror.

Call the point directly in front of the mirror twice as far away as the principal focus the *centre of curvature* of the mirror.

Inf. Infer why it is so called.

Image by a Concave Mirror.

EXPERIMENT 164. (At school.)

In a darkened room place a lighted candle at considerable distance beyond the centre of curvature and a little to the right of it.

Hold a piece of white paper as a screen just to the left of the principal focus, and moving it slowly away from the mirror, see if the image of the candle flame is formed on it.

Obs. Describe the image. (Erect or inverted? Where with reference to the centre of curvature? How large compared with the object?)

EXPERIMENT 165. (At school.)

Bring the candle nearer the centre of curvature, and find and describe the image.

EXPERIMENT 166. (At school.)

Obs. Carry the candle nearer the mirror than the centre of curvature, and find and describe the image.

EXPERIMENT 167. (At school.)

Obs. See if any image is formed when the object is located at the principal focus, within the principal focus, and at the centre of curvature.

Inf. Infer why this is so.

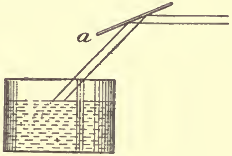

Fig. 54.

k. REFRACTION.

EXPERIMENT 168. (At school.)

By means of a mirror (a) throw a beam of light *obliquely* into colored water, and render the path of rays through the air visible by crayon dust.

Hold a long pencil, or straight stick, parallel with the beam above the water, so that the under side of the pencil will just touch the beam along the upper side, and let the lower end of the pencil extend downward to the bottom of the water.

Obs. Do the rays continue parallel with the pencil after entering the water?

Call the change in direction *refraction.*

Derive the term.

EXPERIMENT 169. (At school.)

Obs. Throw the light perpendicularly into the water, and see if there is any refraction.

DIRECTION OF THE CHANGE.

1. Which is the denser medium, air or water?

Think of a perpendicular to the surface of the water at the point where the light enters the water.

2. Is the light bent toward this perpendicular, or away from it, as it enters the water?
3. Under what conditions have you found that light is refracted, and in what direction are the rays bent?

EXPERIMENT 170. (At home.)

Place a cent in a basin just near enough to one side so that you cannot see it with the eye in a certain fixed position.

Without changing the position of the eye, carefully pour in on the farther side of the basin, so

as not to move the cent, enough water to nearly fill the basin.

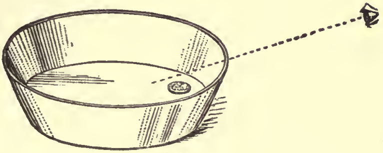

Fig. 55.

Obs. Can you see the cent now?

Inf. Infer in what kind of a line the light must have passed from the cent to the eye.

Compare the direction in which the rays are bent on leaving the water with the direction in which they were bent in Experiment 167 on entering the water.

By a Double-Convex Lens.

A *double-convex lens* is a circular glass body with its sides curved out so as to make it thickest in the centre.

A section of it is shown in Figure 56.

Fig. 56.

A lens 3 or 4 inches in diameter is desirable for these experiments, though a 2-inch lens might answer.

Of Parallel Rays, Principal Focus, Focal Distance.

EXPERIMENT 171. (At school.)

In a darkened room place a double-convex lens in the path of a beam of light so that the light will strike the lens perpendicularly at its centre.

Render the path of the light visible.

Obs. Observe and state how it passes after leaving the lens.

Call the point through which all the refracted light passes the principal focus of the lens.

Inf. What would you call its distance from the lens?

Image of an Object.

EXPERIMENT 172. (At school.)

In a darkened room place the flame of a candle just beyond the principal focus of a double-convex lens.

Obs. Find the image on white paper on the other side of the lens.

Describe the image. (How far away compared with the object? How large? Erect or inverted?)

EXPERIMENT 173. (At school.)

Increase the distance of the flame from the lens, and tell how the image changes.

How far is the flame from the lens when the image is of the same size as the object?

Human Eye.

Describe the human eye and explain how we see.

Simple Microscope.

Look through a double-convex lens at an object located within the principal focus.

Describe the image seen.

Call this lens a *simple microscope.*

Sometimes two or three lenses placed near together are used as a simple microscope.

Derive the term *microscope.*

Compound Microscope.

EXPERIMENT 174. (At school.)

In a darkened room place a candle flame just beyond the principal focus of a small double-convex lens.

Find the image of the flame.

Place a larger lens just beyond the image made by this lens.

Look through the larger lens toward the flame.

Describe the image seen.

EXPERIMENT 175. (At school.)

In a light room substitute any small object for the candle flame, and observe and describe.

Call this combination of lenses a *compound microscope.*

Refracting Telescope.

EXPERIMENT 176. (At school.)

In a darkened room place a candle flame at considerable distance from a large double-convex lens.

Just beyond the image formed by this lens, place a small lens.

Look through the small lens toward the flame, and describe the image seen.

EXPERIMENT 177. (At school.)

In a light room substitute any object for the candle flame, and observe and describe as before.

Call this combination of lenses a *refracting telescope.*

Derive *telescope.*

Tell how the refracting telescope differs from the compound microscope.

Refraction by a Prism. Solar Spectrum.

EXPERIMENT 178. (At school.)

Through a small hole admit light from the sun into a dark room, and have a screen or white wall in the path of the light. (Use a porte lumière.)

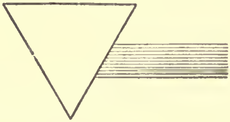

Fig. 57.

What is formed on the screen?
(See Experiment 154.)

EXPERIMENT 179. (At school.)

Hold a glass prism, base upward, in the path of the beam of light.

Observe the change in the position, form, and color of the image.

Infer the causes of these changes.

Call *this* image of the sun the *solar spectrum*.

Derive the term.

Name the colors of the spectrum, beginning at the top.

Inf. 1. Which rays are refracted most?

Inf. 2. Which rays are refracted least?

Write a topical outline of the lessons on light, and a connected composition upon *mirrors* or *refraction*.

PRACTICAL QUESTIONS.

1. When do objects extending upward from the earth cast their longest shadows in the sunlight upon the ground? Why?

2. When do they cast their shortest shadows?

3. Upon what part of the earth are the shadows always long?

4. When and where do such objects cast no shadows?

5. What part of the moon shines?

6. Does it shine upon the earth when it is directly between the sun and the earth?

7. How much of it shines upon the earth at any time?

8. Do the stars shine by their own light, or by the sun's light?

9. Distinguish between a planet and a fixed star.

10. Which planets do you know?

11. Does the earth shine? With its own light?

12. How can the sun be seen before it has risen above the horizon, or after it has sunk below the horizon?

13. When you look obliquely into clear water, why does it appear shallower than it is?

14. In which of the preceding experiments did light from the object actually pass through the points where the image appeared?

Call an image so formed a *real* image.

15. In which experiments did *no* light from the object pass through the points where the image appeared?

Call such an image a *virtual* image.

XIV. CHEMISTRY OF AIR AND WATER.

THE COMPOSITION OF THE AIR.

EXPERIMENT 180. (At school.)

Into a shallow pan pour enough water to make it about 1 inch deep.

Float a bit of red phosphorus as large as a good-sized pea upon a piece of cork in the water.

CAUTION. — Phosphorus must be handled with tongs or forceps, and not touched with the fingers. It should be cut under water, and when not in use should be kept under water.

Carefully light the phosphorus with a match; and, holding an inverted quart jar evenly, lower it slowly over the phosphorus until it rests upon the bottom of the pan, and let it remain there.

Obs. 1. Observe carefully all that takes place under the jar.

Describe the substance formed as the phosphorus burns.

See if it remains under the jar.

Inf. 1. Where must it have gone?

Phosphorus is an element, and is often represented by its symbol P.

Inf. 2. Could the cloudy gas have consisted of P alone?

Inf. 3. What could have combined with P?

Inf. 4. Why did the water rise in the jar?

Obs. 2. Was the P all consumed?

Inf. 5. Why did n't the burning continue?

Obs. 3. How does the part of the air left in the jar compare in volume with that which combined with the P?

Call the part of the air which combined with the P *Oxygen.*

Derive the terms *oxygen* and *phosphorus.*

Call that which remains in the jar *nitrogen.* It is an element, symbol N.

Derive the term.

Call the substance formed by the union of P and O *phosphorus pentoxide.*

Inf. 6. Is it an element or a compound?

Derive the name.

Inf. 7. Infer what proportion of the air is O.

Inf. 8. Infer what proportion of the air is N.

PREPARATION OF OXYGEN.

EXPERIMENT 181. (At school.)

Powder in a mortar a spoonful of thoroughly dried potassium chlorate.

Mix with this an equal quantity of manganese dioxide.

Fill a large hard-glass test tube one third full of this mixture.

Fit a stopper into the mouth of the test tube.

Perforate the stopper and fit into it a glass tube about 16 inches long, bent as shown in the figure.

Cut a hole 1 inch in diameter in the bottom and near the rim of a tin plate (P, Figure 58) 5 or 6 inches in diameter.

Cut another hole $\frac{3}{8}$ of an inch in diameter just below the hem in the rim of the plate and above the hole in the bottom.

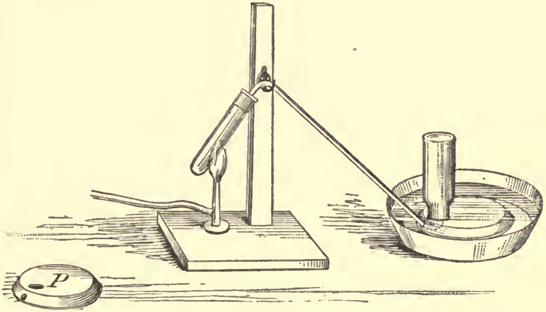

Fig. 58.

Invert this plate in a pan, and pour into the pan enough water to fill it a little above the bottom of the inverted plate.

Fill four horse-radish bottles with water, and, covering the mouths of these with pieces of window glass, invert them, filled with water, upon the bottom of the plate in the pan, placing one of them over the hole in the bottom of the plate, and removing the pieces of window glass.

Support the test tube so that the end of the glass tube will reach beneath the surface of the water in the pan.

Carefully heat the test tube with the gas or alcohol-lamp flame, moving the flame so as to heat the part containing the mixture evenly throughout.

As soon as bubbles begin to escape rapidly from the tube, insert the end of the tube through the hole in the rim of the inverted plate.

When one bottle is filled with gas, promptly close the mouth of it by slipping a piece of window glass under it, remove this bottle, and slip another over the hole in the pan.

In this way fill all the bottles with the gas.

While the bottles are being filled, it may be necessary to dip out a little water, from the pan, to prevent the water from getting too high and floating up the bottles of gas.

Take the delivery tube from the water before removing the flame from the test tube. (Why?)

PROPERTIES OF OXYGEN.

EXPERIMENT 182. (At school.)

Light a splinter of pine wood, and when it gets to burning, blow out the flame and thrust the glowing coal into a jar of oxygen, keeping the jar closed.

Obs. Observe the effect.

EXPERIMENT 183. (At school.)

Wind one end of a piece of wire 10 inches long about a small piece of charcoal, ignite the charcoal, and thrust it into the second jar of oxygen.

Obs. Observe the effect.

The charcoal consists chiefly of the element carbon (C).

EXPERIMENT 184. (At school.)

Wind one end of a piece of wire 10 inches long about a piece of crayon, as shown in Figure 59.

Hollow out the top of the crayon, and, place a piece of roll sulphur (brimstone) as large as a pea in the hollow.

Fig. 59.

Ignite the sulphur and lower it into a jar of oxygen.

Obs. Observe the effect.

EXPERIMENT 185. (At school.)

Heat one end of a piece of fine iron or steel wire, and dip it into powdered sulphur, so as to melt the sulphur and make it stick to the wire.

Ignite the sulphur on the end of the wire, and insert it in a jar of oxygen.

Obs. Observe the effect.

Inf. 1. What do these experiments show about the affinity of oxygen for other elements?

A compound of oxygen with another element is called an *oxide.*

Inf. 2. What different oxides have been formed in these experiments?

Write a connected description of oxygen, — its *preparation* and *properties.*

The rapid union of oxygen with another element accompanied by light and heat is called *combustion.*

Derive the name.

COMBUSTION, COMPOSITION OF WATER.

A candle is composed chiefly of carbon and hydrogen.

EXPERIMENT 186. (At home.)

Light a candle, and hold a cold lamp chimney over it.

Obs. What collects on the chimney?

Inf. 1. What is one substance produced in the burning of the candle?

Inf. 2. What is probably one of the elements of which it is composed? (Recall definition of combustion.)

Let us see if we can learn what the other part of water is.

Fig 60.

EXPERIMENT 187. (At school.)

Fill a horse-radish bottle with water, and, holding a glass plate over its mouth, invert it, and place it in a pan containing a little water.

Wrap a piece of sodium as large as a pea in a paper, and, holding it with forceps, place it quickly under the jar without raising the mouth of the jar out of the water.

Obs. 1. Observe what happens.

Cover the mouth of the jar, and place it upright upon the table.

Light one end of a splinter of pine wood 1 foot long or more, slip the cover aside, and thrust the burning end of the splinter quickly into the lower part of the bottle.

Obs. 2. Observe what happens to the burning stick, and to the gas in the bottle.

Obs. 3. Notice what forms on the inside of the bottle.

Inf. 1. This water was formed in what process?

Inf. 2. Then it was formed from what substances?

Inf. 3. From what substance do you think the gas came? Why?

1. Describe the gas.

[How does it differ from O? (See Obs. 2.)]

It is *hydrogen* (H).

Derive the name. (See *oxygen*.)

Inf. 4. What is water composed of?

Obs. 4. When a lamp or gas is lighted and a cold chimney is placed over the flame, what gathers on the chimney?

Inf. 5. Where do the elements which form it come from?

Let us see if we can learn whether any other substance than water is formed in the burning of the candle.

EXPERIMENT 188. (At school.)

Fit a vaseline bottle, or other wide mouthed bottle, with a good stopper.

Into this stopper fit air-tight two glass tubes, one about 10 inches long, just reaching through the stopper from above, and the other long enough to reach nearly to the bottom of the bottle and project an inch above the top of the stopper.

By means of a piece of rubber tubing 6 or 8 inches long, connect the top of this last tube with the tube of a small tin tunnel

Fill the bottle two thirds full of water.

Obs. 1. Placing the top of the long tube in the mouth, draw in a long breath from the bottle, and observe the effect.

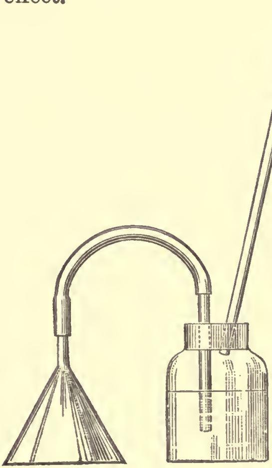

Fig. 61.

Inf. What is the gas that bubbles up through the water? Why does it enter the bottle?

Does the water seem to be affected by it?

Hold the mouth of the tunnel a little above a burning candle, and draw in one or two long breaths as before.

Obs. 2. Is the water affected?

EXPERIMENT 189. (At school.)

Pour out the water from the bottle, and pour in as much lime-water.

Obs. 1. Repeat the two parts of the last experiment just as with water, and notice any effect upon the lime-water.

Obs. 2. Let the bottle stand for a short time, observe any change in the liquid, and notice carefully the bottom of the bottle.

Inf. 1. Infer what the coloring of the liquid was due to.

Inf. 2. Infer how many substances must have combined to form this new substance.

Inf. 3. Infer where they must have come from.

Inf. 4. Could that which came from the burning candle have been the water?

Why not?

Inf. 5. What state of matter was it?

We will prepare some of it in another way.

EXPERIMENT 190. (At school.)

Prepare a horse-radish bottle of O, and, keeping the jar closed as much as possible, repeat Experiment 183.

Inf. 1. Is the substance left in the jar O? How do you know?

Inf. 2. What was it formed from?

Inf. 3. Infer what *element* combined with the oxygen.

The gas formed is called *carbon dioxide.*

EXPERIMENT 191. (At school.)

Obs. Thrust a lighted match into the jar in which the charcoal was burned, and observe the effect.

EXPERIMENT 192. (At school.)

Obs. Lower a lighted candle into the jar, and observe the effect.

In these experiments keep the jar closed as much as possible.

EXPERIMENT 193. (At school.)

Obs. Pour a little lime-water into the jar, shake it, and observe the effect.

Inf. 1. Infer what the substance was which came from the burning candle and acted upon the lime-water.

Inf. 2. What two substances are formed in the burning of a candle?

Supplementary experiments may be taken to see if carbon dioxide is formed in the burning of kerosene, illuminating gas, and wood.

CHANGES IN AIR IN THE HUMAN BODY.

EXPERIMENT 194. (At home.)

Obs. Breathe upon a cool piece of glass or china, and observe the effect.

Inf. Infer one substance given out in breathing.

EXPERIMENT 195. (At school.)

Obs. Refill with lime-water the bottle used in Experiments 188–9, remove the short glass tube from the stopper, push the other tube through the stopper far enough to reach nearly to the bottom of the bottle, breathe out through the glass tube, and observe the effect upon the lime-water.

Inf. 1. Infer another substance given out in breathing.

1. Compare the substances given out in breathing with those formed in the burning of the candle.
2. What substance is taken out of the air in combustion?

Inf. 2. Infer what is taken from the air in the act of breathing.

Inf. 3. What objections are there to breathing the same air over and over?

Inf. 4. Does a lighted lamp or gas jet improve, or injure the air of a room for breathing?

Three men had occupied the closed cabin of a boat for an hour, when it was found that a match would not burn in the cabin.

Inf. 5. Infer why.

Inf. 6. Was such air fit to breathe?

Inf. 7. What must be done with the air of an occupied room to keep it fit for breathing?

Describe fully in writing, with drawings of apparatus, experiments showing changes in the burning candle and in the human body.

Is your school-house properly ventilated?

If so, write a description of the system, with diagrams.

If not, think out a good plan for ventilating it, and present it in writing, with diagrams.

PREFIXES AND SUFFIXES

OCCURRING IN WORDS TO BE DERIVED IN THIS STUDY.

Latin Prefixes.

ad-, at-	=	*to.*
con-, com-, co-, cor-	=	*with, together.*
de-	=	*down, off.*
dif-, di-	=	*apart.*
ex-, e-	=	*out.*
in-, im-, il-	=	*not, into, on.*
non-	=	*not.*
pen-	=	*almost.*
re-	=	*back, again.*
sub-	=	*under, after.*
trans-	=	*across, beyond, through.*

Latin Suffixes.

-able	=	*that may be.*
-al, -ar, -ary	=	*relating to, like.*
-ant, -ent	=	*that which* (in nouns). same as *-ing* (in adjs.).
-ance, -ence	=	*condition, quality.*
-or	=	*that which.*
-fic	=	*making.*
-ian	=	*belonging to.*
-ion	=	*act of, quality of, result of.*
-id	=	*like, relating to.*
-ism, -ity	=	*quality.*
-ive	=	*having the power of.*
-ment	=	*condition.*
-ous	=	*abounding in.*
-ule, -ulum	=	*minute.*

Greek Prefixes.

a-	=	*not, without.*
di-	=	*two.*
pent-	=	*five.*

Greek Suffixes.

-ide	=	*composed of.*
-ize	=	*make, render.*

Anglo-Saxon Prefix.

un-	=	*not.*

APPARATUS AND MATERIALS.

The quantities of materials indicated in many cases will be sufficient for performing the experiment a number of times. Gas or alcohol lamp will be needed in many experiments, and will not be mentioned each time. If desired, apparatus may be ordered from the Publishers, THOMPSON, BROWN & Co., Boston.

I. NATURE OF MATTER.

Exp. 1. Narrow mouth bottle. Exp. 2. Tumbler and tin pan.

II. DIVISIONS OF MATTER.

Exp. 3. Lump of salt, mortar, $\frac{1}{2}$ oz. metallic sodium, small package bleaching powder, 1 lb. commercial sulphuric acid, and a test tube. Exp. 4. Tumbler and $\frac{1}{2}$ oz. bottle of "bluing."

III. STATES OF MATTER.

Exp. 5. Tumbler. Exp. 6. Small stick of sealing wax, string, and 3 or 4 oz. weight. Exp. 7. 2 wide mouth 1 oz. bottles, 2 rubber stoppers to fit (1 with 1 hole and 1 with 2 holes), 3 pieces glass tubing (2″, 3″, and 6″ long), 1′ rubber tubing, and a few drops of red ink. Exp. 8. Test tube, test tube holder, and alcohol lamp or gas.

IV. CHANGES IN MATTER.

Exp. 9. Test tube, bit of copper, and 2 oz. nitric acid.

V. FORCE.

Exp. 10. Chair. Exp. 11. Pail or pan, and chips of wood. Exps. 12, 13. Brick or stone. Exp. 16. Wax and match. Exp. 17. $\frac{1}{2}$ oz. solution of silver nitrate. Exp. 18. Magnet and bits of copper, iron, lead, zinc,

silver, steel, and wood. Exp. 19. $\frac{1}{4}$ yd. silk cloth and straight lamp chimney. Exp. 20. Tumbler, sulphuric acid, zinc and copper plates and connecting wires, $\frac{1}{2}$ lb. potassium bichromate, and a wire magnet. Exp. 21. A cent. Exp. 22. A match. Exp. 23. Tumbler, $\frac{1}{2}$ lb. powdered alum, and thread. Exp. 24. Plate or pan, and 2 glass plates $3'' \times 3''$. Exp. 25. Glass tubes 3″ long of different sizes. Exp. 26. Ammonia, test tube, small wide mouth bottle, $\frac{1}{4}$ lb. powdered charcoal, and filter paper, 4″ diameter. Exp. 27. Ball. Exp. 28. Marble. Exp. 29. Larger marble. (Exps. 28, 29, need not be actually performed.) Exp. 30. Fan. Exps. 31–33. Large book and string. Exp. 34. Same and 64 oz. spring balance. Exp. 35. Spring balance and 3 tin cans, — pint, quart, and 2-quart. Exps. 36–38. Set of lead weight, — 2 of 1 unit, 2 of 2 units, and 2 of 3 units, — mechanical power frame with 2 pulleys fixed 1′ apart, string, pins, foot ruler with tack in each end (in place of bar Fig. 11), and strong manilla envelope.

VI. Gravity.

Exps. 39, 40. Sheet of stiff card-board about $7'' \times 10''$, strong thread and weight, and pins. Exps. 41–46. Thread and 2 weights, — 1 unit and 3 units. Exp. 47. Old clock. Exps. 48, 49. Gem lamp chimney, sheet rubber ($3\frac{1}{2}'' \times 3\frac{1}{2}''$), rubber stopper (1 hole) to fit small end of chimney, 3″ glass tubing, 2′ rubber tubing, and glass funnel. Exp. 50. Same and rubber (or rubber bound) stopper to fit large end of chimney, fitted with jet tube. Exp. 51. Same and 2′ glass tubing, spirit level. Exp. 52. Tin can (pint or larger) with overflow, catch-bucket, or tumbler with string bail, and 4 lb. spring balance. Exp. 53. Spring balance and 4 oz. (or larger) narrow mouth bottle. Exp. 54. T. D. clay pipe, sheet rubber ($3'' \times 3''$), and strong thread. Exp. 55. Tumbler and thin card-board $3'' \times 3''$. Exp. 56. Small glass tube. Exp. 57. Pan and tumbler. Exp. 58, 59. Barometer tube, 5″ strong rubber tubing, strong thread, and 1 lb. mercury. Exp. 60. Glass tube 6″ long and about $\frac{7}{8}''$ bore, with piston to fit. Exp. 61. Lifting pump. Exp. 62. Force pump.

VII. Simple Machines.

Exps. 65–67. Mechanical power frame, lever, and set of weights (2 of 1 unit, 2 of 2 units, and 2 of 3 units). Exps. 68, 69. Wheel and axle. Exps. 70–73. Set of pulleys (3 fixed and 1 movable) and cord (3′), with hooks at ends. Exps. 74, 75. Inclined plane and car, jack-screw, or bench-screw.

VIII. Heat.

Exp. 77. Cent. Exp. 78. Nail, hammer, and anvil. Exp. 79. Marble and wire ring, and alcohol lamp or gas. Exp. 80. Test tube fitted with rubber stopper (1 hole), and 6″ glass tube. Exp. 81. Common thermometer. Exp. 82. Same as for exp. 80. Exp. 83. Tin can, ice, and support for can. Exp. 84. Iron spoon and bit of lead. Exp. 85. Tin can, ice, salt, and small test tube. Exp. 86. Large test tube and test tube holder. Exp. 87. Tin pan and support. Exp. 88. Thin watch crystal and little ether. Exp. 89. Same as for exp. 86 and cold glass. Exp. 90. Thermometer, tin can, and ice. Exp. 94. 6″ iron rod and wire support, 2 marbles, and wax. Exp. 95. Same as for exp. 94 and slate pencil. Exp. 96. Several kinds of wood, iron, cotton cloth, woollen cloth, silk, and thermometer. Exp. 97. Test tube. Exp. 98. Tin can (small mouth) and scales or spring balance. Exp. 99. Tin pan and support, and sawdust. Exp. 100. Apparatus shown in Fig. 37. Exp. 101. Lamp with large chimney and tissue paper. Exp. 102. Oil stove and thin paper. Exps. 104, 105. Small flask and support, chemical thermometer, tin can, perforated stopper to fit flask, and 16″ glass tubing bent as shown in Fig. 39. Exp. 106. 2 test tubes, fine ice or snow, can of hot water.

IX. Magnetism.

Exps. 107–113. 2 magnets (bar and horseshoe), wire nail, iron filings, 6″ steel wire, and silk thread.

X. Frictional Electricity.

Exp. 114. Silk ribbon and $\frac{1}{4}$ yd. flannel. Exp. 115. Large rubber eraser and $\frac{1}{4}$ yd. silk. Exps. 116–122. Large stick sealing wax and flannel, pith-ball and balanced-bar electroscopes, lamp chimney, and silk. Exp. 123. 2 lamp chimneys and silk rubbers, 2 sticks sealing wax and flannel rubbers, 12″ wire bent as in Fig. 45, and silk thread. Exps. 124–127. Chimney, sealing wax, and rubbers, balanced bar, tumbler, 1′ glass tubing, maple rule, and baking powder can and cover.

XI. Voltaic Electricity.

Exp. 128. Same as for exp. 20. Exp. 129. Same and 30′ insulated no. 22 copper wire or helix, 6″ iron rod, and tacks. Exp. 130. Grenet battery (1 qt.) and 3″ fine platinum wire.

XII. Sound.

Exp. 131. Pitchfork (may be borrowed). Exp. 133. Call ball. Exp. 134. Lath or yard stick, and tuning fork. Exp. 135. Tin spice box and cover, and 12′ of string. Exp. 136. Tumbler. Exps. 137–142. Sonometer. Exps. 143, 144. Organ pipe with glass side and membrane, and 18″ rubber tubing. Exps. 145–147. 2 narrow mouth bottles (1 oz. and 4 oz.). Exp. 148. Organ pipe.

XIII. Light.

Exps. 149–153. Porte lumière, piece of window glass, piece of colored glass, and double convex lens. Exp. 154. Soap box, tinfoil 2″ × 2″, and candle. Exp. 155. Darkened room. Exp. 156. Lamp (giving broad flame) and small cube or sphere (½″ or ⅜″). Exps. 157–160. Porte lumière and plane mirror turning on a horizontal axis. Exps. 161, 162. 2 plane mirrors set parallel and at angles (Fig. 53). Exps. 163–167. Porte lumière, convex mirror, candle, and screen. Exps. 168, 169. Porte lumière, plane mirror on axis, glass tank (Fig. 54), and red ink. Exp. 170. Tin pan and cent. Exps. 171–177. Porte lumière, 2 double convex lenses (one with greater focal distance than the other), yard stick and supports, 2 lens holders, lamp or candle and support for same, and screen (all sliding on yard stick). Exps. 178, 179. Glass prism.

XIV. Chemistry of Air and Water.

Exp. 180. Tin pan, flat cork, bit of red phosphorus, and quart glass jar. Exps. 181–185. Same and mortar, ½ lb. potassium chlorate, ½ lb. manganese dioxide, ⅞″ test tube, perforated stopper, 16″ glass tube, 5″ tin plate (P., Fig. 58), and 4 wide mouth bottles (4 oz. or larger), 2 pieces nos. 18–20 iron wire about 12″ long, bit of charcoal, roll sulphur, and 2 fine iron wire. Exp. 186. Candle and lamp chimney. Exp. 187. Tin pan, wide mouth bottle, metallic sodium, and forceps. Exps. 188, 189. Wide mouth oz. bottle, rubber stopper to fit (2 holes), glass tubing 3″ and 6″, small tin funnel, 5″ rubber tubing, and lime water. Exps. 190–193. Jar of oxygen, bit of charcoal and wire, candle, and lime water. Exp. 194. Piece of cold glass or china. Exp. 195. Apparatus used in exps. 188, 189.

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